EOSC 110
INTRODUCTION TO GEOSCIENCES
UNIVERSITY OF SAN DIEGO
LABORATORY READER
FALL 2019

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PLEASE READ

↓

Bring this Reader to every lab session. The purpose of the reader is to supplement the laboratory manual. ALL of the lab exercises you will turn in at the end of each lab session are from this packet. It is essential to have the custom lab manual in addition to this Reader! The lab manual contains mineral and rock identification charts, figures, and information to refer to as you are working through the lab exercises, and preparing for the lab exams.

TABLE OF CONTENTS

GEOLOGIC TIME

THERE are two geologic time problems in this Reader, <u>P. 4</u> (Friday lab) and <u>P. 5 & 6</u> (Monday lab)

You only have to do one, your instructor will assign.

PROBLEM 1: GEOLOGIC TIME SCALE: THE HISTORY OF THE EARTH

Geologic time scale is on page 63 in lab manual, and p. 7 of this Reader

Making a Geologic Time Line (Refer to Geologic Time Scales in Lab Manual, p. 6 & p. 38.)

Procedure: Read the directions carefully to complete the activity.

l. Measure and cut off 5 m of adding machine paper tape.

2. Draw a continuous mid-line down the tape length. See demo for simple method.

3. Daw a zero line across the left end of the tape; label it , "The Present".

4. Near the "The Present" line, make a scale of l cm : 10 million years.

5. From the "Today" line, measure 1 meter to the right along the mid-line and make a vertical mark.
6. Label this mark 1 billion years.

7. Measure and mark each meter after that up to 4 meters or 4 billion years from the present.

8. Now, measure 60 cm to make the total length of the time line 4.6 meters. Mark and label this distance 4.6 billion years (The Beginning of Time).

9. Label the year and name of each era on your geologic time scale. Shade eras to highlight them. Using the scale l cm = l0 million years, measure the distance to each era from Today by using the following information.

ERAS:

a. Cenozoic Era = 66 million years ago = _________________ cm from Today
b. Mesozoic Era : 251 million years ago = _________________ cm from Today
c. Paleozoic Era = 542 million years ago = _________________ cm from Today
d. Precambrian Era = 4.6 billion years ago = _________________ cm from Today

10. Label the major events of each era on your geologic time scale by using the basic geologic time scale as a guide, p. 6 of Lab Manual. Locate and label each of the major events listed below onto your geologic time scale.

Geologic Time Line Major Events

Directions: Label the following Earth events on your geologic time line at proper locations.

Earth forms - 4600 MYA
Moon forms - 4500MYA
Ocean forms - 4300 MYA
Moon Bombarded (Man in the moon forms - 4000 MYA
Oldest known fossil - 3600 MYA
Atmosphere oxygenated - 2300 MYA
Invertebrate explosion - 550 MYA
First fish - 440 MYA
First Land plants - 440 MYA
First trees - 410 MYA
First Land animals - 380 MYA
Coal-forming swamps - 360 MYA
Coal-forming forests - 320 MYA
First Reptiles - 320 MYA
Supercontient Pangaea forms - 260 MYA
Greatest Extinction on Earth - 250 MYA
First mammals - 250 MYA
Dinosaurs begin their domination - 250 MYA
Pangaea begins breaking up - 200 MYA
Formation of Peninsular Ranges Batholith - 180-90 MYA
First flowering plants - 146 MYA
Dinosaurs go extinct - 66 MYA
First humans - 3 MYA
Glaciation peaks in North America - 20,000 YA
Retreat of glaciation in N.A. - 10,000 YA
First Human Civilizations - 8,000 YA
Great Pyramids built - 5200 YA
Fall of Roman Empire - 1533 Y A
Formation of teh USA - 235 YA
Humans land on Moon - 43 YA

LABORATORY REFLECTION Directions: Write a short reflection about your experience in doing the activities in lab today. Include the following: 1) The purpose of the lab; 2) What you learned from this laboratory; 3) What was interesting; 4) The problems and challenges you encountered.

GEOLOGIC TIME SCALE: THE HISTORY OF THE EARTH
PROBLEM 2: See page 63 in lab manual

OBJECTIVES:

- To create a timeline of Earth's history
- To gain familiarity with the metric system
- To get a sense of the scale of human events compared to geologic events

INTRODUCTION:
The Earth has changed dramatically and repeatedly over a history that spans nearly 5 billion years. Such immense spans of time are difficult for most of us to comprehend. They fall outside our range of human experience. We normally deal with much shorter time intervals, like the time of our next class or the number of days until the next exam, or even the number of years until graduation!
It is important for students of the Earth Sciences to expand their sense of time. Extremely slow geologic processes, considered only in terms of human experience, have little meaning. To appreciate the magnitude of geologic time and the history of our incredible planet, you will be creating a timeline of important geologic events scaled to a size more tangible and familiar.
INSTRUCTIONS:

1. Construct a timeline of Earth's history on a long strip of adding machine tape. The timeline should be done to scale.
    - 1 meter (100 cm) = 1 billion years (1000 million years)
    - 10 cm = 100 million years
    - 1 cm = 10 million years
    - 1mm = 1 million years
    - There are ten 100 million years in one billion years, or 100 cm in 1 meter.
    - There are ten 10 million years in 100 million years.

    a) **Measure out a strip of adding machine tape 5 meters long**. A meter stick will be provided in lab.

    b) Select one end of the tape to represent the present. Beginning at that end, **mark off and write each billion years** (1 billion, 2 billion, etc.) at 1 meter increments.

    c) Draw a bold line and **label** (in color) to **show the beginning of the three eras (Paleozoic, Mesozoic, Cenozoic**)
    To help you get started: 542 Million yrs ago from today would be (50 cm+ 4cm + 2mm) from the "today" end of the paper roll, or (40cm + 5cm + 8mm) from the 5 billion mark.

    d) Refer to the **Geologic time scale** in this reader and **p. 63 in the lab manual**. Dates might vary slightly.

    e) **Mark off and write numbers** at 10 cm increments **ONLY WHEN NECCESARY** (plotting boundaries or events)

    f) **Starting with the oldest event** (Event #1), mark off all of the important events in Earth's history shown in the list on the next page. In each case you should **write the date and event directly on the timeline.**

    g) Come up with your own Earth shattering event (do some research), plot the event on your time scale, and present to the class.

2. **Write a brief paragraph** on your perspective of the history of the Earth, or geologic time, that you did not realize before doing this timescale exercise.

For Problem 2: Some Important Events in Earth's History		
Event #	**Date in years before present**	Event
1	4.56 billion	Earth forms
2	4.1 billion	Oldest rock
3	3.9 billion	Oldest evidence of a continent
4	3.8 billion	First evidence of life
5	3.5 billion	First fossils (algae and bacteria)
6	1.8 billion	Free oxygen in atmosphere
7	1.1 billion	First fossil of a complex organism (a worm)
8	540 million	First abundant life found in the rock record
9	460 million	First fish
10	440 million	First land plants
11	410 million	First land animals
12	250 million	Largest mass extinction occurs
13	247 million	First dinosaurs
14	240 million	First mammals
15	220 million	Breakup of super-continent Pangaea begins
16	145 million	First flowering plants
17	65 million	Dinosaurs and other animals go extinct
18	1.8 million	First primate in genus Homo
19	40,000	First Homo *sapiens*
20	13,000	Humans first inhabit North America
21	10,000	End of last Ice Age
22	500	European rediscovery of the Americas
23	?	Your birthday

(Please note that some of these ages may differ slightly from those given in your text or that you found in another source. These dates change, but the general order and rough position stay constant.)

REFLECTION:

THIS TABLE GOES WITH TIME SCALE PROBLEM 2 ON P. 5

0.012 Ma = 11,700 yr. (12,000 yr.)

R. Steinberg
DMC 1-12

Geologic Time Scale

	Eon	Era	Period		Epoch	Boundary Dates (Ma)
	Phanerozoic	Cenozoic	Quaternary		Holocene	0.012
					Pleistocene	2.6
			Neogene	Tertiary	Pliocene	5.3
					Miocene	23.0
			Paleogene		Oligocene	33.9
					Eocene	55.8
					Paleocene	66
		Mesozoic	Cretaceous			146
			Jurassic			200
			Triassic			251
		Paleozoic	Permian			299
			Carboniferous	Pennsylvanian		318
				Mississippian		359
			Devonian			416
			Silurian			444
			Ordovician			488
			Cambrian			542
PRECAMBRIAN	Proterozoic	Neo-	Ediacaran			~635
		Meso-				
		Paleo-				2500
	Archean					4000
	Hadean		*No Rock Record on Earth*			
			ORIGIN OF EARTH			~4600

Note #1: Vertical timeline of boundary dates *is not* drawn with a uniform scale.
Note #2: Boundary dates from the International Commission on Stratigraphy 2010 Geologic Time Scale
Note #3: Carboniferous, Paleogene, and Neogene are more commonly used outside of the U.S.
Note #4: Epochs for the Mesozoic and Paleozoic are too numerous to be shown.
Note #5: The Hadean Eon is not formally recognized.

MINERALS AND DENSITY EXERCISE

Please Review Mineral pgs. 78-89 in the Lab Manual

Pre-lab due at the beginning of lab.

Pre-lab_Minerals

Look at Mineral Exercise on pages 69-94, in lab manual. Answer the following on scantron form.

1. Which of the following does not fit the description of a mineral?
   a) inorganic
   b) specific chemical formula
   c) lacking crystalline structure
   d) naturally occurring
   e) both c and d

2. Which mineral group is considered to be the major rock forming mineral group, and the most common mineral group?
   a) silicates b) carbonates c) sulfates d) oxides e) halides

3. This mineral has excellent cleavage in one direction, a hardness of 2 to 2.5, is colorless (sometimes yellow-brown), and has OH in the silicate structure. *(look at the mineral charts on p. 92-94)*
   a) halite b) gypsum c) muscovite mica d) serpentine e) quartz

4. All of the following are useful physical properties except ________________.
   a) streak d) luster
   b) size e) cleavage
   c) hardness

5. Corundum is the mineral name for ___________________________. (need to google this)
   a) sapphire
   b) diamond d) ruby
   c) emerald e) both a and d

6. Which 2 minerals are not classified as silicates?
   a) pyroxene and olivine d) quartz and k-feldspar
   b) halite and gypsum e) muscovite and hornblende
   c) plagioclase and biotite

7. Which of the following is not characteristic of olivine? *(look at the mineral charts on p. 92-94)*
   a) green color
   b) hardness of 6.5 to 7
   c) prominent cleavage
   d) nonmetallic

8. The 2 directions of cleavage for hornblende meet at _______ angles. *(look at the mineral charts on p. 92-94)*
   a) 90 degree
   b) 30 and 60 degree
   c) 45 degree
   d) 120 and 60 degree

9. The hardness for calcite is _______ *(look at the mineral charts on p. 92-94)*

   a) 3 b) 2 c) 5 d) 6 e) 7

CRUSTAL DENSITY HYPOTHESIS TESTING **NAME ______________________________**

You will do an experiment to test how mass and volume affect the density of two different rock samples.

Hypothesize what your group thinks will occur given a light (felsic) and a dark (mafic) rock sample**:**

- *Density = mass/volume*
- *A hypothesis is a tentative, testable answer to a scientific question.*

Hypothesis:

Run the following experiment to test your hypothesis. Read through these instructions before you start your experiment.

Determining the density of a rock sample. To determine the density you will use the displacement method to measure the volume of granite and gabbro samples. Measure water displaced using the plastic graduated cylinders. Each tick mark on the cylinders represents **5 cm^3** (same as 5 mL) of volume. *Make sure this is correct, you might have a different size cylinder*. It is important to read the water level to the nearest **1 cm^3** (nearest 1 mL), which means estimating as best you can between each tick mark. *Do this as accurately as you can; this is the largest source of error in this part of the lab.* **See pg. 10-12 in lab manual for help.**

EXPERIMENT

Directions: Follow steps below to complete the data tables for the three samples of granite and gabbro.

- Fill the plastic cylinder to between the 300 and 350 mL level. Tap the cylinder to get out air bubbles.
- Weigh the first sample and record the **mass** in grams for "Sample 1."
- Read the water level to the nearest 1 cm^3 (nearest 1 mL) and record it in the table under "start level" for "Sample 1".
- Tilt the cylinder to ~ 45 degree angle and gently slide the sample in so that it slips into the water without splashing.
- Gently tap the cylinder to get out air bubbles.
- Read the water level to the nearest 1 cm^3 and record it in the table under "end level" for "Sample 1."
- See p. 10-11 in lab manual for help with using graduated cylinders.
- Calculate the **volume** of the sample (in cm^3) by subtracting the start level from the end level.
- Calculate the **density** of the sample (g/cm^3) by dividing the weight (in g) by the volume (in cm^3).
- **Without removing the water or rocks from the cylinder**, repeat above steps for the rest of the granite samples. *Note: the "start level" for each successive sample will be the same as the "end level" of the previous sample.*
- Calculate the average density of the **three samples of granite**. By taking the average of three separate density measurements, we will hopefully cancel out some measurement errors and obtain a more accurate value for the density.
- **Repeat this procedure using the 3 gabbro samples**. Start with a new cylinder of water. While some students are completing the table for the granite, the others in the group can start measuring the gabbro samples

GRANITE

Sample number	Mass (g)	Start level (cm^3)	End level (cm^3)	Volume (cm^3)	Density (g/cm^3)
Sample 1					
Sample 2					
Sample 3					

Average density of **granite** samples = mass/volume = _______________ g/cm^3
SHOW WORK:

GABBRO

Sample number	Mass (g)	Start level (cm^3)	End level (cm^3)	Volume (cm^3)	Density (g/cm^3)
Sample 1					
Sample 2					
Sample 3					

Average density of **gabbro** samples = mass/volume = _______________ g/cm^3
SHOW WORK:

ANALYSIS:

1. Which rock type has the greatest density? ________________________
2. Do the results support or refute your hypothesis? Why?
3. Briefly describe the relationship between the size of the sample and the displacement of the water:
4. Briefly describe the relationship between the size of the sample and the weight.

5. Apply the results of your experiment to a "real world" situation?

6. List 2 to 3 variables that will affect the density of rock (less or more)?
   -
   -
   -

7. Pick one variable from #6 above and formulate a hypothesis about how it will influence the density of the rock.

Hypothesis:

MINERALS

READ THIS

MINERAL IDENTIFICATION CHARTS ARE ON P. 90-91 IN THE LAB MANUAL.

Use the worksheets on p. 92-94 IN THE LAB MANUAL to organize the mineral information.
You can modify the table headings to personalize the identification sheets.

Once you finish with identification your instructor will give you the correct sample numbers, place the numbers below. You can also add these numbers to your worksheets. Same numbers are on the reserve samples in the library which you can check out at the reserve desk for 2 hrs.

SILICATE MINERALS: *There might be more than one sample for certain minerals. Write all numbers down.*

- ______ **Quartz**
- ________ ______ Plagioclase (Ca,Na)-feldspar
- ______ ________ K-feldspar (**Orthoclase** and Microcline)
- ______ Muscovite mica
- ______ Biotite mica
- ______ Olivine
- ______ Augite (pyroxene)
- ______ Garnet
- ______ Tourmaline (not in lab manual, see info. on the board in classroom)
- ______ Hornblende (amphibole)

NONSILICATE MINERALS

- ______ **Calcite**
- ______ Halite
- ______ **Gypsum**

Bold font: Mohs scale minerals.

ROCKS

Please Review the following in the Lab Manual

pages 102-119

Pre-lab due at the beginning of lab.

PRE-LAB_IGNEOUS AND SEDIMENTARY ROCKS

Refer to pages 105-109 in the lab manual and study the igneous rock identification table on p. 108, take the time to be familiar with this chapter. Answer the following on scantron form.

1. When there are 2 different sizes of crystals (minerals) caused by different cooling rates; the larger minerals are called phenocrysts. What is the texture?

a) aphanitic
b) phaneritic
c) coarse-grained
d) porphyritic

Match the numbered word to the letter definition (#2-6)

2. Mafic a) term used for light colored igneous rocks, or minerals, high in silica, potassium and sodium

3. Granite b) a mineral high in Fe (Iron) and Mg (magnesium) that is found in peridotite

4. Felsic c) dark, glassy-textured rock or volcanic glass

5. Obsidian d) term used for dark colored igneous rocks, or minerals, high in Fe (Iron) and Mg (magnesium)

6. Olivine e) large minerals, felsic, intrusive igneous rock

Match the intrusive igneous rocks to their extrusive equivalents (#7-10):

7. Granite	a) Basalt
8. Diorite	b) Rhyolite
9. Gabbro	c) extrusive equivalent rare
10. Peridotite	d) Andesite

11. The igneous rocks you matched in #7 to 10 have the same chemical composition, but the textures (size of minerals) are different. The intrusive rocks are composed of large, or visible, minerals and the extrusive are made of much smaller minerals. In lab, you will learn some of the terms used to describe igneous textures. For now, what controls the size of the minerals found in igneous rocks?

a) cooling rate (fast or slow cool)
b) where the molten rock solidifies and crystallizes (below the surface in the crust, or on the surface)
c) chemical composition of surrounding rock (country rock)
d) the amount of silica in the molten rock
e) both a and b

Refer to pages 110-115 in the lab manual.

12. _______ **does not** play a role in the formation of sedimentary rocks (see rock cycle on p. 103)?

a) weathering
b) transportation
c) compaction
d) melting
e) deposition

Match the numbered word to the letter definition (13-17)

13. limestone a) this detrital (clastic) sedimentary rock is made of angular-shaped gravel-sized sediment

14. shale b) classified as an evaporite

15. sandstone c) a detrital sedimentary rock composed of mud (clay)-sized particles

16. breccia d) made of calcium carbonate ($CaCO_3$), classified as a biochemical sedimentary rock when has a marine organic origin.

17. gypsum e) the sediment found in this detrital rock ranges from 1/16 to 2 mm in diameter

18. All of the following are classified as detrital sedimentary rocks except ________.

a) conglomerate
b) sandstone
c) siltstone
d) coal
e) shale

19. Chalk is classified as a __1___ sedimentary rock and has an abundance of ___2____

a) 1. chemical 2. fossils
b) 1. biochemical 2. microscopic shells
c) 1. detrital 2. rock fragments
d) 1. detrital 2. feldspar
e) 1. biochemical 2. coral fragments

20. The following rocks are classified as fine to very fine-grained detrital sedimentary rocks ___

a) shale, and siltstone
b) conglomerate, breccia, and quartz sandstone
c) rock gypsum and chert
d) micrite and chalk

IGNEOUS ROCKS
READ THIS

IGNEOUS ROCK IDENTIFICATION CHART IS ON P. 108.

Use worksheet on p. 110 in lab manual to describe igneous rock information.   You can modify the table headings to personalize the identification sheets)

Once you finish with identification your instructor will give you the correct sample numbers, place the numbers below. You can also add these numbers to your worksheets. Same numbers are on the reserve samples in the library, you can check them out at the reserve desk.

THERE MIGHT BE MORE THAN ONE SAMPLE, WRITE ALL NUMBERS DOWN.

INTRUSIVE IGNEOUS ROCKS

- ________ **Peridotite**
- ________ **Gabbro** ↔ Basalt
- ________ **Diorite** ↔ Andesite
- ________ **Granodiorite**
- ________   ________ **Granite** (2 samples: different #s) ↔ Rhyolite
- ________ **Granite Pegmatite** *(google term pegmatite)*

EXTRUSIVE IGNEOUS ROCKS

- ________ **Basalt**
- ________ **Andesite** (2 samples: same #)
- ________ **Rhyolite** (2 samples: same #)
- ________ **Obsidian**
- ________ **Pumice**

"Tonalite" is similar to Granodiorite.

MAKE SURE YOU CHECK OUT OTHER BOXES, NOT ALL SAMPLES LOOK THE SAME!

SEDIMENTARY AND METAMORPHIC ROCK ID LIST

READ THIS

SEE the **Sedimentary Rock classification chart available in lab**. **USE THE WORKSHEET ON P. 114 TO FILL IN SEDIMENTARY ROCK INFORMATION.**

SEE the **Metamorphic Rock classification chart available in lab**. **USE WORKSHEETS ON P. 120 TO FILL IN METAMORPHIC ROCK INFORMATION.** **You can modify the table headings.**

SEDIMENTARY ROCKS

DETRITAL

- _______ **Breccia**
- _______ **Conglomerate**
- _______**Quartz Sandstone**

Mudstones (silt and/or clay)

- ________ **Siltstone**
- ________ _______ **Shale** (2 samples: different #s)
- ________ **Claystone**

CHEMICAL

- ______ **Chert**
- ______ **Rock Gypsum**

BIOCHEMICAL

- ______ **Fossiliferous limestone**
- ______ **Chalk**
- ______ **Crystalline limestone (Micrite)**

METAMORPHIC ROCKS

- ______ **Schist**
- ______ **Marble**
- ______ **Gneiss** (maybe 2 samples w/ 2 different #s)
- ______ **Slate**
- ______ **Quartzite**

TAKE HOME CONVERSION EXERCISE **NAME: ______________________________**

Directions: Do the following calculations. To receive credit, please show your work.
See http://serc.carleton.edu/mathyouneed/units/index.html for help (this link is on Bb).
See conversion chart on next page and p. 37 in manual.

Unit Conversion Problem	**Unit Conversion Calculation**: **SHOW WORK HERE**
Example: 2.5 miles = 4.0 kilometers	2.5 mi x 1.6 km/mi = 4.0 km (miles cancel)

a. 10.0 miles = _______ kilometers

b. 1.0 foot = ______ meters

c. 16 kilometers = ______ meters

d. 25 meters = ______ centimeters (cm)

e. 1.3 liters (L) = ______ milliliters (ml) or cubic centimeters (cm^3)

f. 25.4 mL = ______ cm^3

g. 120 pounds = ______ kilograms (kg)

h. 2 ounces = ______ grams

i. **Velocity = distance/time**. An object travels 280 miles in 4 hours, the velocity of the object: _______ **km/hr**
show work:

Scientific Notation *see p. 14 and 15 in manual for help*
We convert very large or small numbers to scientific notation in order to shorten them and to make them easier to manipulate in expressions. For example:

- 19,000,000 = 1.9×10^{7}
- 0.0000000756 = 7.56×10^{-8}

1) Write one billion (1,000,000,000) in scientific notation. ____________________________________

2) Write 276,000,000 in scientific notation. ______________________________________

3) Write 0.00000000602 in scientific notation. ____________________________________

4) Convert 100,000,000 cm to km, give answer in scientific notation ________________ **km**
(100cm = 1m; 1000m = 1km) **show work:**

Mathematical Conversions

To convert:	To:	Multiply by:	
kilometers (km)	meters (m)	1000 m/km	**LENGTHS AND DISTANCES**
	centimeters (cm)	100,000 cm/km	
	miles (mi)	0.6214 mi/km	
	feet (ft)	3280.83 ft/km	
meters (m)	centimeters (cm)	100 cm/m	
	millimeters (mm)	1000 mm/m	
	feet (ft)	3.2808 ft/m	
	yards (yd)	1.0936 yd/m	
	inches (in.)	39.37 in./m	
	kilometers (km)	0.001 km/m	
	miles (mi)	0.0006214 mi/m	
centimeters (cm)	meters (m)	0.01 m/cm	
	millimeters (mm)	10 mm/cm	
	feet (ft)	0.0328 ft/cm	
	inches (in.)	0.3937 in./cm	
	micrometers (µm)*	10,000 µm/cm	
millimeters (mm)	meters (m)	0.001 m/mm	
	centimeters (cm)	0.1 cm/mm	
	inches (in.)	0.03937 in./mm	
	micrometers (µm)*	1000 µm/mm	
	nanometers (nm)	1,000,000 nm/mm	
micrometers (µm)*	millimeters (mm)	0.001 mm/µm	
nanometers (nm)	millimeters (mm)	0.000001 mm/nm	
miles (mi)	kilometers (km)	1.609 km/mi	
	feet (ft)	5280 ft/mi	
	meters (m)	1609.34 m/mi	
feet (ft)	centimeters (cm)	30.48 cm/ft	
	meters (m)	0.3048 m/ft	
	inches (in.)	12 in./ft	
	miles (mi)	0.000189 mi/ft	
inches (in.)	centimeters (cm)	2.54 cm/in.	
	millimeters (mm)	25.4 mm/in.	
	micrometers (µm)*	25,400 µm/in.	
square miles (mi2)	acres (a)	640 acres/mi^2	**AREAS**
	square km (km^2)	2.589988 km^2/m	
square km (km2)	square miles (mi^2)	0.3861 mi^2/km^2	
acres	square miles (mi^2)	0.001563 mi^2/acr	
	square km (km^2)	0.00405 km^2/acr	
gallons (gal)	liters (L)	3.78 L/gal	**VOLUMES**
fluid ounces (oz)	milliliters (mL)	30 mL/fluid oz	
milliliters (mL)	liters (L)	0.001 L/mL	
	cubic centimeters (cm^3)	1.000 cm^3/mL	
liters (L)	milliliters (mL)	1000 mL/L	
	cubic centimeters (cm^3)	1000 cm^3/mL	
	gallons (gal)	0.2646 gal/L	
	quarts (qt)	1.0582 qt/L	
	pints (pt)	2.1164 pt/L	
grams (g)	kilograms (kg)	0.001 kg/g	**WEIGHTS AND MASSES**
	pounds avdp. (lb)	0.002205 lb/g	
ounces avdp (oz)	grams (g)	28.35 g/oz	
ounces troy (ozt)	grams (g)	31.10 g/ozt	
pounds avdp. (lb)	kilograms (kg)	0.4536 kg/lb	
kilograms (kg)	pounds avdp. (lb)	2.2046 lb/kg	

To convert from degrees Fahrenheit (°F) to degrees Celsius (°C), subtract 32 degrees and then divide by 1.8 To convert from degrees Celsius (°C) to degrees Fahrenheit (°F), multiply by 1.8 and then add 32 degrees.

*Formerly called microns (µ)

From Pearson: AGI & NAGT Lab Manual in Physical Geology 10th ed.

PLATE TECTONICS

Read the questions carefully in the lab manual and write your answers in the reader. Some activities will require you to write in the lab manual, see instructions on the following pages.

PART I: ISOSTASY (OR ISOSTACY) **NAME____________________________________**

Introduction: Why does the Earth have continental areas and oceanic areas? Rephrasing the question a bit, why does the Earth's surface divide into two distinct regions of elevation: the **continents** (average elevation about 0.5 miles above sea level), and the **ocean basins** (average elevation about 2.3 miles below sea level)? The answer relates to the fact that Earth's surface is made up of two different types of crust: the **continental crust** and the **oceanic crust**. These two types of crust differ in both their **thickness** and **density**. In this lab, you will see how these two properties control the elevation of the continents versus the ocean basins.

Relationship between Volume, Mass, & Density

- **Density** is a measure of mass per unit volume.
- **Water:** a gallon (a unit of volume) weighs about 8.33 pounds (a unit of mass). Therefore, the **density** of water is 8.33 pounds per gallon.
- We can use any measurement of mass and/or volume to express **density of water**:
    - o 62.4 pounds per cubic foot (62.4 lbs/ft^3)
    - o Kilogram per liter (1.0 kg/L)
    - o 1 gram per cubic centimeter (1.0 gm/cm^3) = 1.0 gram per milliliter (1.0 gm/mL).
- In this exercise, we will use the standard Metric System unit for density, **grams per cubic centimeter (gm/cm^3).**
- To measure the **density** of something in **gm/cm^3**, we need to measure both its **mass in grams** and its **volume in cubic centimeters**.
    - Measuring **mass** is easy; we just weigh the object on a scale.
    - We will measure volume by the first method. If the container that the wood blocks are floating in was graduated, then the 2nd method would be an alternative.
        - o by linear dimensions
        - o by water displacement *(see p. 10-11 in lab manual)*.

SEE PAGES 12-13 IN LAB MANUAL

Question 1: Heft the pieces of oak and redwood in your two hands. Which one feels denser (heavier for a given amount)?

____

Determine the density of oak and redwood.

1) Weigh the blocks to the nearest gram.
2) Use a ruler to measure, in centimeters, the length, width and height of the blocks.

OAK: **Weight:** ____________ **Length:** ___________ **Width:** ___________ **Height:** ____________

Volume by ruler: cubic cm (cm^3) (length x width x height): ____________________ *include units*

Density (linear): (weight / volume): __________________ gm/cm^3 (round to nearest 0.01)

Show work:

REDWOOD: **Weight:** __________ **Length:** __________ **Width:** _________ **Height:** __________

Volume by ruler: cubic cm (cm^3) (length x width x height): __________________ *include units*

Density (linear): (weight / volume): _______________ gm/cm^3 (round to nearest 0.01)

Show work:

Question 2: The density of water is 1.0 gm/cm^3. Comparing the density of water to the density of Oak and redwood, **predict** what proportion (percent) of your blocks will stick up out of the water when the pieces of wood are floating.

OAK: _________ % of the block will be underwater, and __________ % will stick out of the water.

REDWOOD: _________ % of the block will be underwater, and ________ % will stick out of the water.

Question 3: Take the pieces of redwood and oak and float them in water. Do your predictions in #2 above fit with what you see?
Draw below a simple side view sketch of the two blocks across the waterline, labeling each block and showing how different proportions stick above the water. (Note: Keep this observation in mind when you do the final part of the lab.)

OAK **REDWOOD**

____ **water line**

Question 4: Think about what you saw with the blocks of oak and redwood floating. What effect did the difference in density between the two types of wood have on how high each one floated?

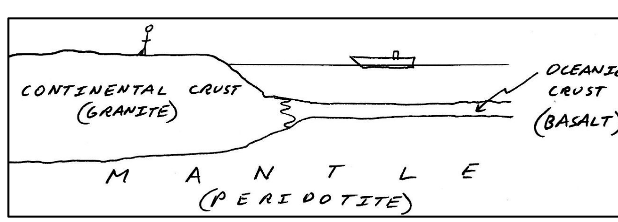
ISOSTATIC EQUILIBRIUM OF THE EARTH'S CRUST (*see pages 12-13 in lab manual)*

In this part of the lab, we will see how differences in the density and thickness of rock control the elevations of the Earth's crust. We'll also see how the crust adjusts when loads of weight are added or taken away.
The Earth is made up of two kinds of crust: continental crust and oceanic crust. **Continental crust**, which is mostly **granite** and rocks of similar density, makes up the continents. **Oceanic crust** is mostly the rock **basalt**, which makes up the floors of the ocean basins. Both types of crust lie on the Earth's **mantle**, which is mostly the rock **peridotite**. The illustration below shows that the continental crust and the oceanic crust have different thicknesses. Continental crust averages about 35 km thick (more underneath mountains), while oceanic crust averages about 5 km thick. The two types of crust, and the underlying mantle, also differ in their density. Most Earth rocks range in density from about 2.6 to about 3.3 gm/cm^3 -- even small differences in density can have important effects.
The geologist Clarence Dutton proposed decades ago that the Earth's two types of crust "float" buoyantly on the mantle, much in the way that an iceberg or a block of wood floats buoyantly in water. He called this condition **isostasy** (Greek for "equal standing"). When the crust floats in a balanced, stable manner in the mantle beneath, we have a condition called **isostatic equilibrium**. This turns out to be a very useful concept, as you will see.

Density of the continental crust (granite): 2.7 gm/cm^3

Density of the oceanic crust (basalt): 3.0 gm/cm^3

Density of the upper mantle (peridotite): 3.3 gm/cm^3



Question 5: What is the connection between wood floating in water and the crust (either type) floating in the mantle? Use specific values of density for wood, water, crust, and mantle in your answer.

Question 6: Imagine a thick block of wood and a thin block of wood, both with a density of 0.5 gm/cm^3 floating in water next to each other. Would the tops be at the same level? Why or why not?

Draw below, an accurate side view sketch showing how these two blocks would look floating next to each other. Note: "accurate" here means that you need to consider the density of the wood relative to water.

thick block of wood | **thin** block of wood

____ **water line**

Question 7: Geologists know that the continental crust is much thicker underneath mountain ranges than it is in low areas. Thinking about your answers above, explain why.

Question 8: Thinking about all of your answers above, explain why the continental crust stands above sea level while the oceanic crust lies more than two miles (on average) below sea level. Your explanation should take into account both thickness differences and density differences.

Question 9: **SEE article on table**. The "rows" of raised beaches located 100 to 250 km from the present-day coasts of Hudson Bay and James Bay are one of the most powerful visual reminders that the land has risen about 1 to 1.3 meters per hundred years, and continues to rise. *https://www.ontariobeneathourfeet.com/rising-land-isostatic-rebound/*

Connect your explanation for the rising Hudson Bay beaches to this exercise:

PART 2: MEASURING & EVALUATING PLATE MOTIONS:

Earth's lithospheric plates slowly move laterally over the asthenosphere – driven by a combination of heat, gravity, and differences in rock density. Geologists use several methods to establish plate velocities: **1)** analysis of hot spot traces, **2)** analyze the age-dated magnetic signature in the oceanic crust, and **3)** offset rocks, stream drainages, or other features along transform faults.

100 cm = 1 meter 1000 meter = 1 kilometer 1 million yr = $1x10^6$ yr

SEE LAB MANUAL FOR THE FOLLOWING ACTIVITIES

PROBLEM 1: *** ACTIVITY 3 ON P. 145 AND FIGURE 13 ON P. 135 ***

The Hawaiian Islands and Pacific Plate Motion: Follow the instructions and answer **A1 through A4**, **NOT A5,** and **A6.**

ANSWERS should be in **cm/yr.** **Helpful website: http://serc.carleton.edu/mathyouneed/rates/index.html**

A 1)

A 2) Rate __________________________SHOW WORK:

Direction ______________________ Also, draw an arrow to illustrate your answer:

(see figure at bottom of this page for help)

A 3) Rate ____________________________ SHOW WORK:

Direction of plate movement _______________ Also, draw an arrow to illustrate your answer:

A 4) Rate ____________________________ SHOW WORK:

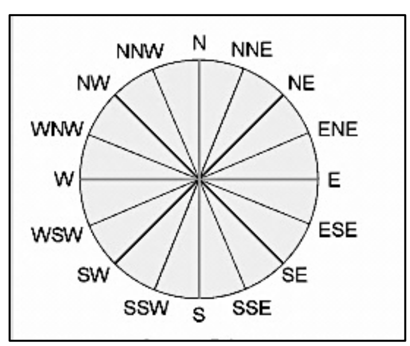
Direction of plate movement _______________ Also, draw an arrow to illustrate your answer:

A 6) Reflect and Discuss:

Answer the question in the manual and explain why you chose the direction of movement above in problem A3 and A4.

Cardinal Compass Points

http://geokov.com/education/compass-directions-azimuth.aspx



PROBLEM 2: ***** ACTIVITY 5 ON PAGE 149 and 150 *****

- Read A on p. 149
- Do **A1 through A6**: **write in lab manual**, tear out and turn in with these reader pages.

PROBLEM 3: ***** ACTIVITY 6 ON PAGE 151 and 152 *****

- Read A on p. 65
- Do **A1 and A2 (p. 151), B, and C (p. 152)**: **write in lab manual**, tear out and turn in with the reader pages.
- **Show your work** for all problems in the **blank area on p. 152. Clearly indicate which problem correlates with your work .**

Post Lab Exercise: Laboratory Reflection: Turn this in with the rest of the exercise.
Directions: Write a reflection (minimum 120 words in length) about your experience in doing the plate tectonic exercises lab today. Include the following: **1)** What was the purpose of the lab? **2)** What did you learned from this laboratory? **3)** What did you find interesting? **4)** What were the problems and challenges you encountered; and **5)** Your opinion on how this lab was designed (the good or bad).

TAKE HOME ASSIGNMENT:

PICK-UP THE WORLD BATHYMETRIC CHART PROVIDED AT END OF LAB BEFORE LEAVING.

Directions: Illustrate the major plate tectonic boundaries (see **figure 1 on p. 125 in the lab manual and figures in the lecture text**).

1) Draw in the three different plate boundaries found worldwide according to boundary type.

2) Draw and label each of three boundary types with a different color. Make a legend.

3) Label (by name) each of the major tectonic plates – 14 plates total

4) Draw motion arrows to show the relative motion of the Pacific and North American Plates:

- Near Hawaii to show the direction and speed of the Pacific Plate.
- On the opposite sides of the San Andreas Fault to show the direction and speed of both the Pacific and North American Plates

RELATIVE DATING EXERCISE **Name: ____________________________**

Directions: See pages 54-70 in lab manual. Complete the analysis and evaluation of the geologic cross sections **1 through 4 (Activity 2) on p. 69-70.**

FOR EACH GEOLOGIC CROSS SECTION, DO THE FOLLOWING:

1. Determine the relative ages for the rock bodies and other geologic features/events, including, tilting, uplift, faulting, and erosional unconformities.

2. List the sequence of geologic events (each one is labeled with a letter) in chronologic order by writing down the letters from oldest (bottom of list) to youngest (top of list) in the column of blanks. For each dated event you must also indicate which stratigraphic law was used to place the event in its proper time slot. Use the following initials for the stratigraphic laws: **SP** = superposition, **IN** = inclusions; **CC** = cross-cutting, **UN** = unconformity.

3. Determine and name (**by type)** all the lettered unconformities found in each cross-section.

Geologic cross section #1		Grand Canyon cross section #2	
Age Sequence	**Stratigraphic Law**	**Age Sequence**	**Stratigraphic Law**
(Youngest) ______	______	(Youngest) _____	______
______	______	______	______
______	______	______	______
______	______	______	______
______	______	______	______
______	______	______	______
______	______	______	______
______	______	______	______
______	______	______	______
______	______	______	______
______	______	______	______
______	______	______	______
______	______	______	______
______	______	______	______
______	______	(Oldest) ______	______
______	______		
(Oldest) ______	______		

Geologic Cross section #1

Type of Unconformity

R ____________________________

S _____________ and _______________

O ____________________________

P____________________________

Grand Canyon section #2

Type of Unconformity

R _______________ and ___________________

S ______________________________

Geologic cross section #3

Geologic cross section #4:

Age Sequence	Stratigraphic Law
(Youngest) ______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
(Oldest) ______	______

Geologic cross section #3

Type of Unconformity

N ______________________________

Z ______________________________ (between D and J)

O ________________________and ________________

C ______________________________

Age Sequence	Stratigraphic Law
(Youngest) ______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
______	______
(Oldest) ______	______

Geologic cross section #4

Type of Unconformity **(omit CC and Q)**

Y _______________________

XX ____________________

W _____________________

U _____________________ and _______________

P _____________________

PRE-LAB EXERCISE_TOURMALINE BEACH FIELD TRIP

SEE TOURMALINE BEACH FIELD TRIP INFORMATION ON BLACKBOARD, **and the geologic time scale on p. 63 in the lab manual.**
Answer the following on this page and turn in with the rest of the exercise.

1. During your field trip you will walk north along the beach, then observe the layers of sedimentary rocks as you walk south, back to the cars in the parking lot. Where are the oldest rocks located at Tourmaline Beach?
   a) the south end of the beach
   b) the rocks are all the same age
   c) the north end of the beach

2. The oldest sedimentary rocks exposed at Tourmaline Beach are ________________ in age.
   a) Mesozoic c) Paleozoic
   b) Cenozoic d) Holocene

3. The rocks you will see at your first stop are called the Mt. Soledad Formation. The Mt. Soledad Formation is Eocene in age and composed of _______________________.
   a) fossiliferous limestone
   b) siltstone
   c) sandstone and siltstone
   d) conglomerate and sandstone
   e) siltstone and claystone

4. The next formation you will observe, and describe, as you walk along the beach is mostly mudstone (like claystone) and siltstone. What is the name of this formation?
   a) Friars Formation
   b) Del Mar Formation d) Scripps Formation
   c) Linda Vista Formation e) Cabrillo Formation

5. The next, younger, sedimentary rock layer is called the San Diego formation, these rocks are mostly sandstone that is poorly cemented and ________________________.
   a) fossils are abundant.
   b) is interpreted to be a river deposit.
   c) is interpreted to be a deep marine in origin.
   d) includes dinosaur bones.

6. The Mt. Soledad and Scripps Formations are Eocene in age, this epoch starts at ______ and ends at ____________. (Ma = millions of yrs ago)
   a) 54.8 Ma 33.7 Ma
   b) 5.3 Ma 1.8 Ma
   c) 65.5 Ma 54.8 Ma
   d) 1.8 Ma 11,000 yr

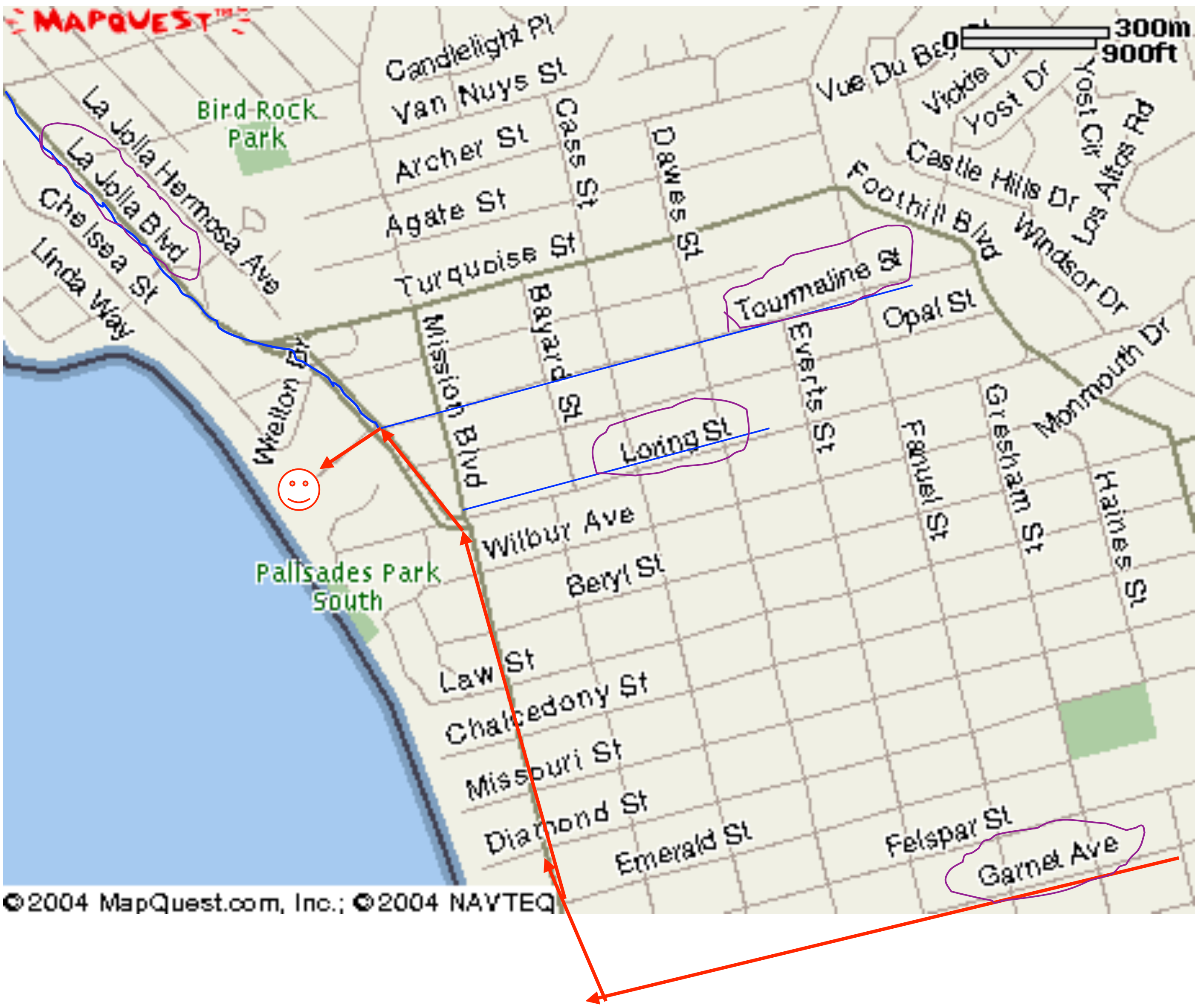
7. We are living in the _________________ period.
   a) Jurassic
   b) Devonian d) Quaternary
   c) Tertiary e) Cambrian

TOURMALINE BEACH FIELD TRIP: please be there by 3:00PM

BRING FOLLOWING READER PAGES WITH YOU: #31 to #35

Driving instructions:

- Interstate 5 North to Grand/Garnet exit
- From left lane, turn left on to Grand
- Follow Grand to Mission Blvd
- Turn right on to Mission Blvd.
- **Fork to left from Mission Blvd at Loring on to La Jolla Blvd**
- Turn left from La Jolla Blvd on to Tourmaline St.
- Go down the steep hill into the parking lot at Tourmaline Surfing Park



TOURMALINE BEACH EXERCISE

Introduction & Purpose: The coastal geology of San Diego County is beautifully exposed in bluffs of Tourmaline Surf Park. **Sedimentary rocks of Cenozoic ages** were deposited there within various types of coastal marine depositional settings over time. Several unconformities and an ancient fault are also exposed there. The purpose of this lab is to observe, describe, sketch, photograph, and interpret various geologic features in the sea cliff at Tourmaline Surf Park.

Directions:

- **Answer the fieldtrip questionnaire.**
- **Complete the stratigraphic section for Tourmaline Beach** on the stratigraphic section blank provided.
- Fill in the section with the proper geologic symbol for the rock type represented for each interval of rock type observed. See the table of rock symbols for the correct symbol used to indicate the various rock types.
- Give the formation name and age that would appear on a geologic map for that unit.
- **Write a brief description of each formation on the diagram** in the space adjacent to the specific rock unit. This description should include:
    - The range of rock types in the formation (For example, conglomerate with lenses of silty sandstone.)
    - A standard geologic description of the rock type. (For example, if the rock is a conglomerate with silty sandstone matrix: estimate the size range of clasts and matrix material, describe the composition of the clasts and matrix material, the roundness or angularity of the clasts, the sorting of the clasts.)
    - Other observations: fossils observed, unusual minerals, sedimentary structures, the presence of graded bedding or cross bedding or other features that tell something about the depositional environment.

I. LOWER SECTION ROCKS AT THE NORTH END OF BEACH: CABRILLO AND MT. SOLEDAD FORMATION

The Mt Soledad Fm. is exposed in the cliff and is early **Tertiary Period/Eocene Epoch** in age (**52 million years**).

1) What specific rock type(s) make up the Mt Soledad Formation? (Hint: two types; one being coarse-grained detrital sedimentary rock containing large rounded rock fragments):

- **Rock types :**______________________________ and ___________________________________

2) Estimate the rock fragment sizes within the Mt Soledad Formation (consider the pebbles and cobbles clasts, AND finer-grained matrix):

- Avg Clast size: ____cm

3) Name the **three major rock types that make up the cobbles** in the Mt Soledad Formation.

- 1) 2) 3)

4) The Mt Soledad Formation contains a unique set of cobbles, called **"Poway" clasts**, which have an exotic origin. List the rock type and age for the "Poway" clasts.

RockType: ___________________________________ Age ________________

5) Briefly explain where these exotic clasts came from, and how they ended up in this formation in coastal San Diego.

6) What was the most likely depositional environment for the Mt Soledad Fm? ______________________________

7) Place the Mt Soledad Formation on your Stratigraphic Column Worksheet.

II. OBSERVATIONS AND ANALYSIS OF THE TOURMALINE FAULT

There is a fault that cuts and offsets the Mt Soledad and Scripps Formations here. Make observations and take measurements of the fault:

1) **Fault Strike and Dip:** ___________ and ____________

2) **Offset Motion:** Hanging Wall moved Up or Down__________

3) **What type is fault is it**? ______________ **What type of stress** ? ______________________________

III. OBSERVATIONS AND ANALYSIS OF THE SCRIPPS FORMATION:

Here we observe the **Scripps Formation unconformably overlying the Mt Soledad Formation**. Note that the entire section of rocks here are tilted (dipping) to the south. **This tilting is due to the growth of Mt. Soledad** a few miles to the northeast. Mt. Soledad is being pushed up along a compressional bend in the Rose Canyon Fault Zone. Therefore, as we head south we will be walking "up-section" through the whole sequence, where the Mt Soledad Formation will eventually pass under the beach, giving way to the overlying Scripps Fm.

The Scripps Formation is also Eocene age (approx. 46 million years old) and formed in the middle to lower sections of an offshore sea submarine canyon.

1) Note the **contact between the underlying Mt Soledad Fm and the overlying Scripps Fm**.
Is this contact considered **an unconformity**? If so, which type? ____

2) What specific rock types make up the **Scripps Formation**?

Answer: ___________________________________ and ______________________________________

3) What's the special name for the package of numerous, thin layers in the Scripps Fm?

Answer: ____

4) How do turbidite layers form? ____

5) What 2 sets of evidence in the Scripps Fm indicates that the sediments in this formation were deposited in a submarine canyon environment? What are they?

Answer:____and ____

6) Estimate the dip angle (tilt angle with respect to the horizontal) of the Scripps Formation. Are these rocks **dipping toward the north or south?**

Dip angle: ______________

7) As you continue walking north along the base of the sea cliff, notice how "messed up" (folded, swirled, etc.) the Scripps Formation is in some spots. These irregular swirls are the result of underwater mass movement events (slides, slumps, etc.) that occurred in this rock unit as it was being formed. **Did this deformation occur when the Scripps Formation was still soft sediment or after it hardened into a rock?**

Answer: ____

8) **Now, walk down the beach along the base of the sea cliff**. Keep walking south until you notice a series of criss-crossing fractures filled with a **very soft, clear mineral.** This mineral was precipitated inside cracks in the rock by groundwater. What mineral is this? Hint: it's very soft and it doesn't fizz in hydrochloric acid.

Answer: ________________________

9) LABEL and sketch the Scripps Formation on your Stratigraphic Column Worksheet.

IV. UPPER SECTION STOPS - SOUTHERN END OF TOURMALINE BEACH: SAN DIEGO FORMATION:

Before you reach the parking lot, higher up on the sea cliff, is a layer of conglomerate that overlies the Scripps Formation. This rock layer forms the base of the **Pliocene San Diego Formation (less than 3 million years old).** Observe the south-dipping contact between the underlying Eocene Scripps Formation and the overlying Pliocene San Diego Formation.

1) Type of unconformity bounds the Scripps and San Diego Fms? ____________________________

2) What span of **time** does this unconformity comprise? _________ my

3) What specific **rock types** make up the **San Diego Formation**? There are three.

Answer: ________________________, ________________________, and ______________________________

4) Further down the beach, south of the parking lot, you'll notice that the sandstone exposed in the sea cliff contains numerous fossils within the San Diego Formation. Identify and record all the different **fossils** you observe. Note: at a minimum, you should be able to find at least two different types of fossils. Look carefully! You'll see 'em!

Fossil #1: ____________________________________ **Fossil #2:** ____

5) What 2 sets of evidence in the San Diego Fm indicates that the sediments in this formation were deposited in a rather quiet warm shallow bay environment?

-
-

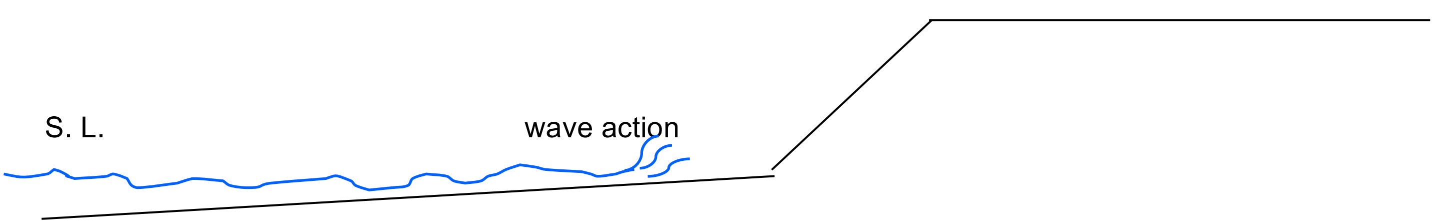
6) LABEL and SKETCH the San Diego Formation on your Stratigraphic Column Worksheet.

V. Based on field observations at Tourmaline Surfing Park and the introductory comments, answer the following:

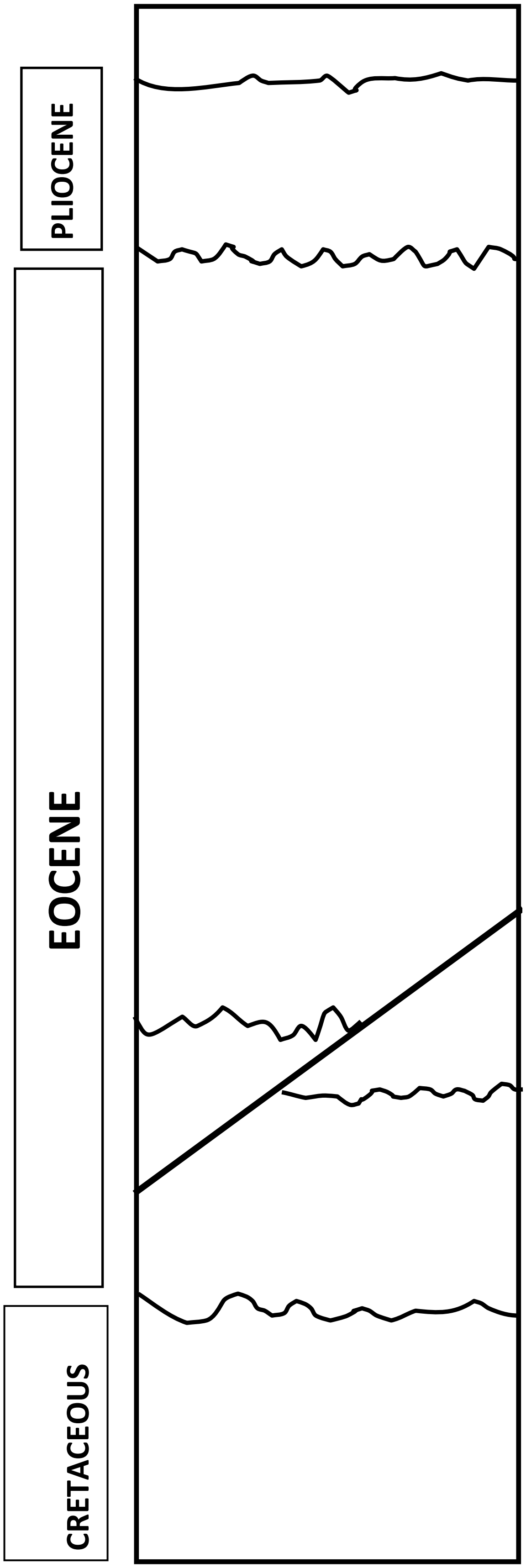
Question 1: On the diagram below label the following: **a)** sea cliff**, b)** abrasion platform, **c)** marine terrace

Question 2: Name two geological processes that will create a marine terrace (a former abrasion platform).

-
-



Tourmaline Beach Stratigraphic Column



Field Notes:

UNCONFORMITY: ________________

UNCONFORMITY: _________________

FAULT: Strike: _______ Dip: _____ Type : ______________

UNCONFORMITY: _________________

UNCONFORMITY: _________________

TOPOGRAPHIC MAPS

Please Review pgs. 155-175 and p. 5-8 In Lab Manual. Pages 160 and 161 will be very helpful.

pre-lab questions due at the beginning of lab.

The following will be posted on Bb

GOOD SITES TO REVIEW MAPS:

- **San Diego Topographic maps:** http://www.efghmaps.com/SAN_DIEGO/index.html
- http://www.ghosttowns.com/topotmaps.html

HELPFUL WEBSITES:
http://serc.carleton.edu/mathyouneed/slope/index.html
http://serc.carleton.edu/mathyouneed/slope/slopes.html
http://serc.carleton.edu/mathyouneed/slope/topoprofile.html
http://academic.brooklyn.cuny.edu/geology/leveson/core/linksa/vertexag.html **HELP WITH VE**

PRE-LAB_TOPOGRAPHIC MAPS

Refer to pages 5-8 and 155-175 in the lab manual. Answer the following on scantron form.

Match the numbered word to the letter definition (1-5)

1. Fractional scale	a. difference in elevation between 2 points on a map
2. Bar scale	b. townships and ranges
3. Topographic profile	c. 1 unit on the map represents 24,000 units of same units on Earth's surface or ratio scale
4. Public land survey	d. used to measure distance on a map
5. Relief	e. allows a "side-view" perspective

Study the rules for contour lines on p. 170-171. Answer the true/false questions (6-9).

6. Every point on a contour line represents the exact same elevation.
7. Contour lines always cross one another on the map.
8. The farther apart the contour lines are on the map, the steeper the slope.
9. Contour lines form a V pattern when crossing streams that points downstream.

Match the numbered word to the letter definition (10-14)

10. Latitude	a. can be traced through England, Africa, and the south Atlantic
11. Longitude	b. shortest distance between 2 places on Earth
12. Prime Meridian	c. east-west distance on Earth,
13. Great Circle	d. north-south distance, measured as an angle from the center of Earth
14. The Equator	e. 0^{o} 00' 00''

15. What is the correct latitude for San Diego?
    - a) 32^{o} 45' N
    - b) 117^{o} 08' W
    - c) 30^{o} 30' N
    - d) 116^{o} 45' W
    - e) 35^{o} 32' 45'' N

16. What is UTM zone for San Diego (p. 164)?
    - a) 5
    - b) 11
    - c) 16
    - d) 32
    - e) 116

TOPOGRAPHIC MAP EXERCISE: Yosemite Valley Topographic Map
SEE PAGES 5-8 and 155-175 In Lab Manual for help **Name: ___________________________**

Section A: Topographic Fundamentals and Features

1. In what years was this map published or revised? _______________, _________________

2. What organization created this map? ____

3. How was topographic contouring of this map generated? _________________________

4. What type of map projection was used to create this map? __________________________

Coordinate Systems

5. Write **latitude & longitude coordinates** the two corners of this map? **(include hemisphere letter)**

	NE Corner	**SW Corner**
Latitude:	________________	_________________
Longitude:	________________	_________________

6. Latitude & longitude interval (arc distance) tick marks, along edge of the map, are ________ minutes apart.

UTM:

7. Which **UTM zone** is this map area located in? ______________________

8. What color are the **UTM** coordinate tick marks found along the outside edge of this map?
   Answer: __________________

9. The blue **UTM** tick mark intervals along the edge of the map are __________ meters apart.

10. What are the **UTM** coordinates for each of the two corners of this map? **(include units & E or N)**

	NE Corner	SW Corner
Easting:	_________________	_________________
Northing:	_________________	_________________

Map Scale

11. What is the ratio scale of this map? ________________

12. What is the verbal scale of this map? ____

13. One inch on this map equals exactly _______________ inches of real ground distance.

14. One centimeter on this map equals ________________ kilometers of real ground distance.

15. Roughly, how many square miles of real ground does this map cover (Including Legend area)? _______________

Magnetic Declination

16. What is the magnetic declination? ___________ East or West declination? ______

17. The declination is based on what year? _______________

18. Name the topographic map that continues to the NE of this map? __________________

Map Features and Symbols

19. Meaning of the solid green pattern ___________, & the small dotted green pattern _______________.

20a. What do red dashed or solid lines represent? ________________________________ [Hint: Related to PLS]

20b. What do associated red numbers indicate? ____________________________________ [Hint: Related to PLS]

21. Difference between the black dashed and solid double lines?______________________

22. What type of symbols represents buildings on the map? _________________________

Section B: Location, Bearing, and Distance
Establishing Location

23. Interpolate the best approximate latitude and longitude for these locations **(include hemisphere letter)**:

	Half Dome	*El Capitan*
Latitude:	________________________	_________________________
Longitude:	________________________	__________________________

24. Interpolate the best approximate latitude and longitude for these locations **(include hemisphere letter)**:

	Quarter Domes	*Liberty Cap*
Latitude:	________________________	_________________________
Longitude:	________________________	__________________________

Establishing Bearing and Distance

25. Determine the bearing and distance **from** Half Dome **to** Clouds Rest.

Quadrant bearing: _________________

Azimuth bearing: _________________

Distance (miles): _________________

26. Determine bearing & distance **from** Glacier Point (triangular BM, 7214') **to** Bridalveil Fall, where Creek crosses 4800' contour.

Quadrant bearing: _________________

Azimuth bearing: _________________

Distance (miles): ________________

Section C: Contours and Surface Relief
Contours

27. What is the contour interval of the map? ______________

28. What is the contour interval between the dark/thicker contour lines? _____________

29. What is the datum base level & date used to establish contour and point elevations on this map?______________

30. What is the highest measured elevation (benchmark, in feet) on this map? ________________

31. What is the lowest measured elevation (benchmark, in feet) on this map?(see Merced River) ______________

32. What is the total relief of this area? (Difference between highest and lowest elevations?) ___________________
show work:

Contours Patterns
33. Tightly-spaced contour lines represent what type of geographic feature? _____________

34. Broadly-spaced contour lines represent what type of geographic features? ____________

35. Sets of contour lines that form "V"-shaped patterns pointing to lower elevations represent what sort of general geographic feature? (hint: either stream channels or ridge lines) **Answer**:______________________

36. Sets of contour lines that form "V"-shaped patterns that point to higher elevations represent what sort of general geographic feature? (hint: stream channels or ridge lines?)

Answer:______________________

Geographic Features
37. Which direction does the Merced River Flow through Yosemite? East or West?

Answer:___________________. Determined by: _____________________, or ________________

38. What special name is used in Yosemite Valley for high promontories that form flat-topped "bulls-eye" contour patterns? (hint: rhymes with "home") **Answer:___________________**

SECTION D: Topographic Profiles Across Yosemite Valley:

1. Construction of the Tenaya Creek Profile A-A'
Instructions: Construct a topographic profile of the eastern end of Yosemite Valley across Tenaya Creek from the intersection of red section line & SW ridge on Mt. Watkins (A) to the top of Clouds Rest (A').

a. **REVIEW THE INSTRUCTIONS FOR CREATING PROFILES IN YOUR LAB MANUAL P. 251**
b. **Use only enough index (dark/bold) contour lines to allow you to construct a complete profile.**
c. Do not vertically exaggerate (your vertical scale is the same as your horizontal) or use vertical scale given by the instructor.

2. Construction of the El Capitan Meadow Profile B-B'
Instructions: Construct a topographic profile of the central portion of Yosemite Valley across The Merced River from the top of KP Pinnacle on El Capitan (B) to the top of Cathedral Rocks (B'). Review points a-b-c above used for Tenaya Creek profile.

Comparison between the Tenaya Creek and the El Capitan Meadow Profiles
39. Describe the general shape of each of the profiles across Yosemite Valley ("V" or "U"?)

Tenaya Creek Profile A-A' ___________________; El Capitan Meadow Profile B-B' ________________________

40. Which erosional agent is primarily responsible for the shaping of these two sections of Yosemite Valley? Choose between water, ice, and wind. Briefly explain your choice.

Tenaya Creek Profile A-A' - ____

El Capitan Meadow Profile B-B' - ____

SECTION E: Vertical Exaggeration Exercise (VE)

COMPLETE IN LAB MANUAL: Activity 9.6 on p. 264, TOPOGRAPHIC PROFILE CONSTRUCTION:

VERTICAL EXAGGERATION TAKE-HOME EXERCISE Name: ___________________________

****Color copy will be circulated in class****

Use the elevation profile below to complete this exercise.

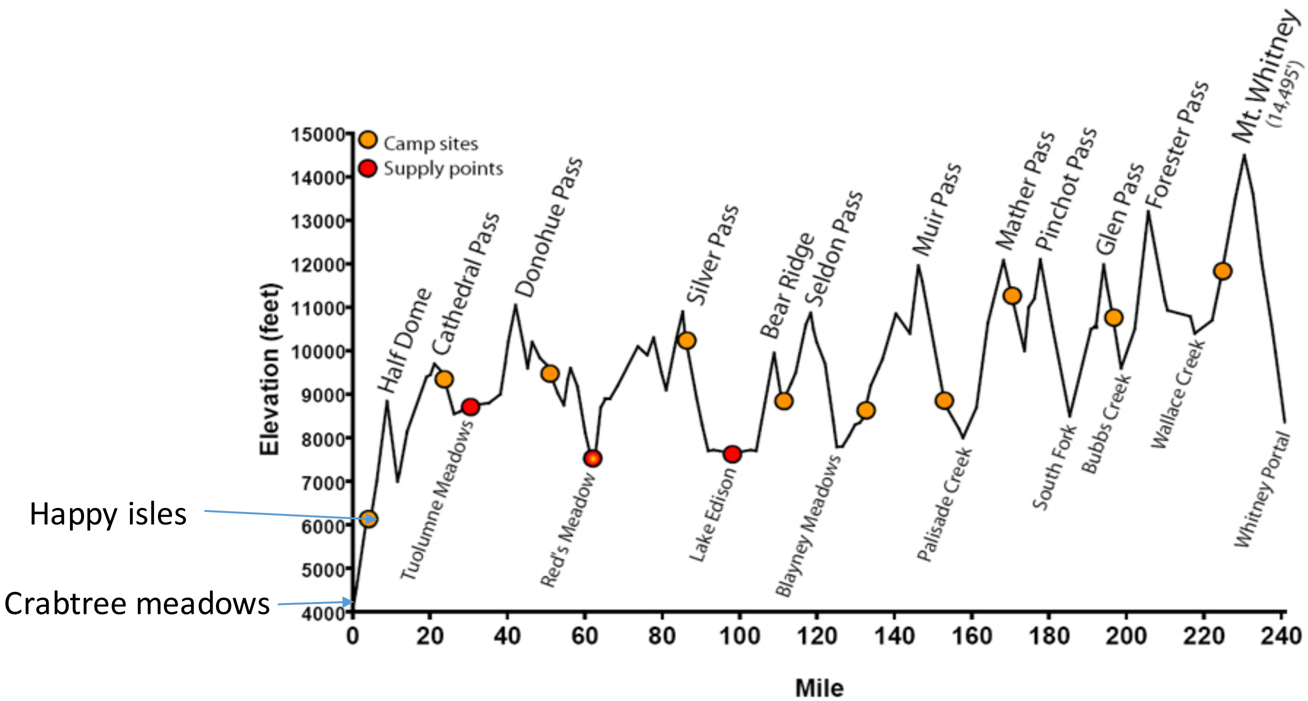


Figure 1: Elevation profile of the John Muir Trail (source: http://hikeforcancer.tripod.com/jmt.html)

1) You are planning to backpack the 200+ mile **John Muir Trail**, which passes through Yosemite, Kings Canyon, and Sequoia National Parks (lucky you!). Using the topographic profile above, **answer the following questions** to help plan your trip. *Show ALL work to receive full credit.*

a. What is the **vertical scale** of the topographic profile?

b. What is the **horizontal scale** of the topographic profile?

c. Calculate the **vertical exaggeration** of the topographic profile.

Show work:

d. Why is it important to know the vertical exaggeration of the profile when planning your hike?

e. What is the **gradient** from Whitney Portal to Mt. Whitney (peak)? *Give your answer in both ft/mile and %.* **Show work:**

______________ ft/mi

_______________ % slope

f. What is the **gradient** from Crabtree Meadows to Mt. Whitney (peak)? *Give your answer in both ft/mile and %.* **Show work:**

______________ ft/mi

_______________ % slope

g. Name **one other major peak** that is important to consider in planning your hike, and give its elevation. Calculate the **gradient** starting from both sides of the peak (as you did in questions e and f).

h. Based on your answers to questions **e, f, and g**, would you start your backpacking trip at Happy Isles or Whitney Portal. Why? *Use numerical values to enhance your answer.*

HELP WITH SLOPE!

Convert gradient to % slope:

- start with: Gradient = 60ft /mile
- change miles to feet, so feet cancel
- 60ft / 5280ft = .01 (5280ft = 1 mile)
- .01 x 100= 1% slope

GEOLOGIC STRUCTURES

Please Review pgs. 189-204 in Lab Manual

HELPFUL INFORMATION

STRUCTURAL GEOLOGY: PLEASE READ

Introduction & Purpose: Structural geology is the study of how geologic rock units are initially arranged and later deformed. Changing spatial relations between geologic units and the stress and strain that occur during deformation events are key aspects in understanding geologic structures. The purpose of this lab is to both learn and apply the concepts of structural geology to reading and interpreting geologic structures including tilted beds, folds, and faults. The terms and concepts of geologic structures, the application of structural geology to mountain building events, and the techniques used to interpret geologic structures will be presented and discussed. The three types of graphic representations of geologic structures: 1) geologic maps, 2) geologic cross sections, and 3) block diagrams will also be highlighted and discussed. The purpose of this laboratory exercise is to become successful at applying the principles of structural geology for both, interpreting surface and subsurface structural and geologic relations, stress and strain regimes, and solving structural problems, concerning geographic regions that expose a rock record of igneous, metamorphic, and sedimentary events, folding and faulting, and surface erosion.

PART I. Knowing and Understanding Structural Terms and Symbols

A. Measuring the Attitude of Rock Units

Attitude is the spatial orientation of planar rock structures. Two aspects of attitude are needed to constrain a rock unit or surface orientation in three-dimensional space: **1) Strike and 2) Dip**. **Strike** is the compass bearing of a line formed by the intersection of a horizontal plane and the (inclined) plane of the layered rock feature. Strike can be expressed as either a quadrant, or an azimuth bearing.

Dip is the angle between the horizontal plane and the planar rock unit or feature. **Dip** direction is always down the inclined plane and is perpendicular to the strike. Strike and dip are drawn on geologic maps as a "T-like" symbol – the long segment is the strike; the short segment the dip. A number nest to the short segment represents the dip angle. In the field, geologists measure attitude with a compass (strike) and an inclinometer (dip).

B. Geologic Map Symbols

Geologic symbols are used on geology maps to indicate one or more characteristics of the rock formation at the point on the map that they (the symbols) are placed. Some commonly used map symbols are found in **Figure 4 on page 194** (you will refer to these symbols for interpreting and making geologic maps, cross sections, and block diagrams). Map symbols indicate 1) attitude (e.g. strike and dip of either, bedding or foliation), 2) formation contacts, 3) fault lines (rock type, location, and planar orientation), 4) fold axes (type, location, and their limb orientations), and 5) rock formation information (type, name, and age). You will need to be able to recognize and interpret these symbols while working on geologic maps and diagrams.

C. Major Types of Geologic Structures

Mappable rock units are called formations. Locations where rock formations are exposed at the earth's surface are called outcrops. Undisturbed rock formations such as sedimentary beds and lava flows are typically horizontal and planar in spatial orientation. However, shifting tectonic plates produce a variety of stresses in the crust that will, over time, cause crustal deformation such as uplift, tilting, erosion, faulting, and folding of formations. Faults and folds exposed at the earth's surface in outcrops have unique structural characteristics that can be recorded, mapped, identified, categorized, and analyzed.

D. Rules for Interpreting Geologic Structures ***REMEMBER THESE RULES***

Carefully study and use these rules to complete the lab exercise.

1) Layers of rock dip downward towards where the youngest rock layers are exposed at the surface.

2) The older rocks are exposed in the center of eroded anticlines and domes.

3) The younger rocks are exposed in the center of eroded synclines and basins.

4) Plunging anticlines form "U" shaped outcrop belts (map view). The plunge arrow points towards the closed end of the "U".

5) Plunging synclines form "U" shaped outcrop belts (map view). The plunge arrow points towards the open end of the "U".

6) The steeper the dip of a layer, the more narrow its exposed width where it crops out at surface (map view).

7) In reverse faults (compressional stress), the hanging wall tends to move up relative to the footwall (pushed together).

8) In normal faults (tensional stress), the hanging wall tends to move down relative to the footwall (pulled apart).

9) Strike of bedding or planar rock formations is parallel to direction of rock formation contacts on the map view.

STRUCTURE LAB EXERCISE **Name: __________________________**

Drawing and Interpreting Geologic Structures in Block Diagrams

Introduction: Three-dimensional geologic block diagrams are simplified scaled-down models of Earth's crustal rock structures, which include 1) formations, 2) unconformities, 3) faults, and 4) folds. The top of the block diagrams is called the **map-view** (ground surface), whereas, the sides are called **cross-sections** (vertical, side-views beneath the ground surface). Visualize the 2-D representations as 3-D structure.

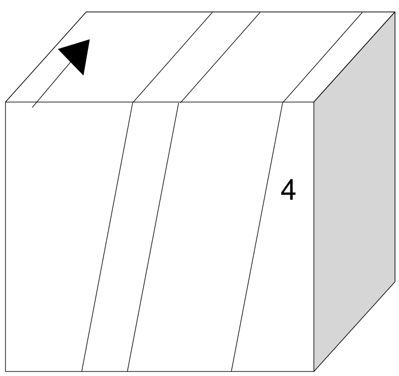
Proper writing syntax:

STRIKE: N so many degrees E or W, e.g., **N75ºW.**

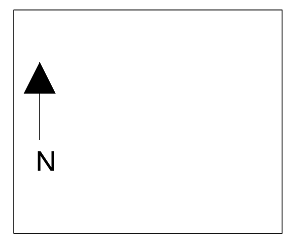
DIP: so many degrees below horizontal & quadrant compass direction, e.g. **52^{o}SW.**

Block Diagram [perspective sketch to appear 3-dimensional – to appear like a 3-D object] - Made from map and cross-section views.

1. **a) Complete map view** showing 4 beds with strike and dip symbols on beds. **b) Complete the cross-section** and put correct numbers on each bed to indicate relative age.



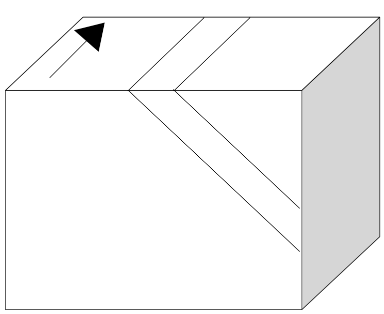
Geologic Map→

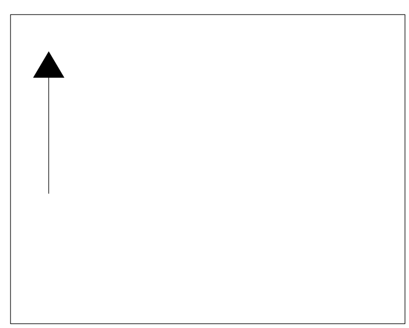


Cross-Section →

2. **Complete map view**

a) Draw **bed contacts** [boundary between two beds, drawn as a line]**; b) relative age numbers on beds** [by convention, #1 is the oldest bed]; **c) strike and dip symbols.**



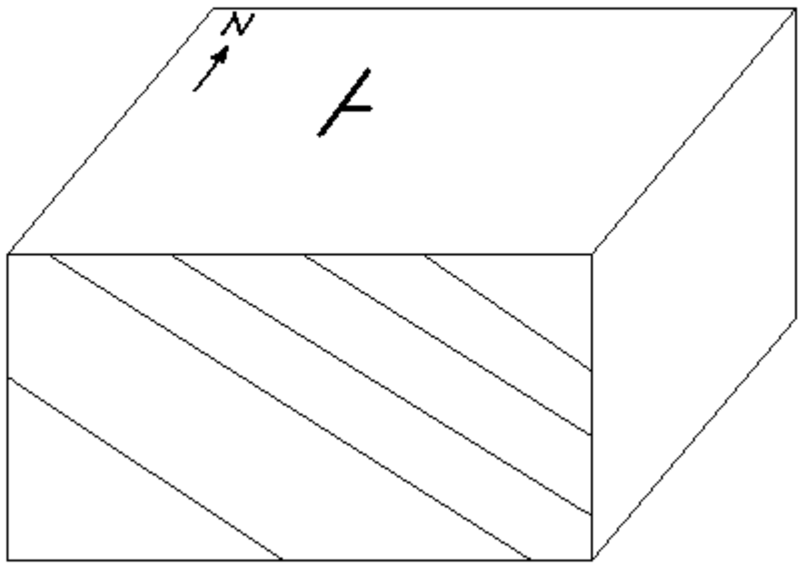


d. Describe orientation of 3 beds drawn on geologic map with: Strike ______________________; Dip __________.

e. The youngest bed is: ________________ (give its correct number)

f. The oldest bed is: ________________ (give its correct number)

3.Tilted sedimentary beds:

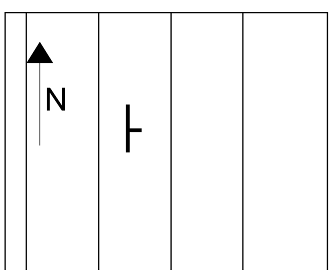


a) Measure the **dip** of the sedimentary beds and record (degrees and compass direction):

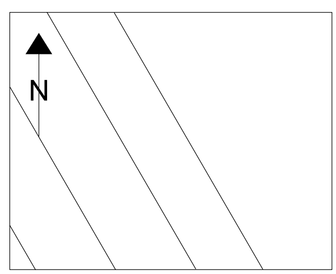
____

b) Draw the bed contacts on the map.

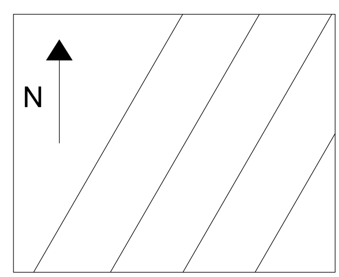
USE *SAME* CROSS-SECTION GIVEN IN BLOCK DIAGRAM *ABOVE*.



Map i.



Map ii.



Map iii.

The 3 maps here show variations of strike direction but have same cross-section.

i. This is current MAP, defined by the block diagram printed above.

ii. Same 6 beds with different strike.

iii. Same 6 beds with even different strike.

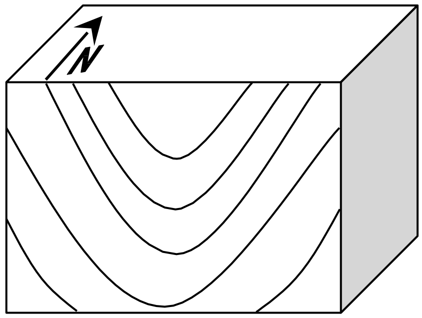
Strike for Map i.: ____________________

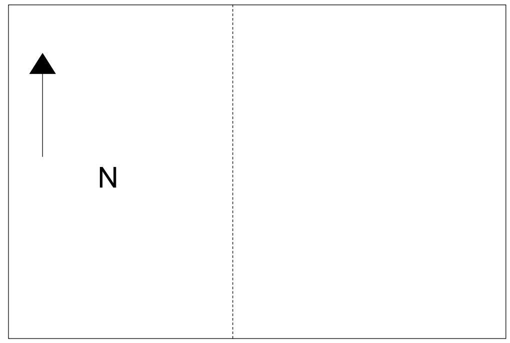
Strike for Map ii.: ____________________

Strike for Map iii.: ____________________

4. Folded, but <u>non-plunging</u> sedimentary beds. The axis (center) of fold is parallel to the North arrow and shown in geologic map view as a dashed line.

a. **Add contact lines** to Map view and list STRIKE of fold axis: ________________





b. Determine the **STRIKE of the beds**: ____________________________________

c. Estimate visually the **angle and direction of the DIP of the beds** to the **<u>west</u>** of the fold axis:

___________________________________(remember the correct syntax)

d. What is **angle and direction of the DIP of the beds <u>east</u>** of the fold axis? ______________________________

e. **Number the beds** on the **cross-section face** of the block. (Number 1 is oldest.)

f. What bed is youngest? _____________________ (give bed number) [by convention, #1 is the oldest bed]

g. Remembering that sedimentary beds are "originally horizontal", this now-deformed geologic feature is called:

____

h. Stress or stresses that could produce this series of deformed beds: __________________________________

i. Tectonic boundary or boundaries that could produce this deformation: _______________________________

j. Which three of the numbered "Rules for Interpreting Geologic Structures "have you "proved" or demonstrated by working this question?

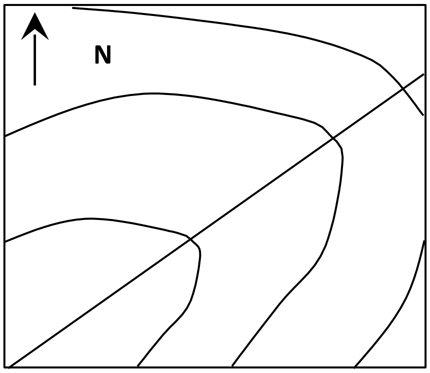
____

____

____

5. Folded feature: Observe the axis of this fold is not oriented North and South.

Added observations: - Contact lines between beds are curved.
- The unit or bed in SW corner of map is early Silurian age.
- The rock unit in NE corner is late Silurian age.



a. What is this deformed geologic feature called?

____

b. What compass direction does it plunge? __________________________

c. Measure and record the STRIKE of the fold axis here: ____

d. The average DIP **direction** of beds, along the fold axis is: ______________________________

e. The beds SE of the axis in the map DIP in what general, compass quadrant direction? _________________________

f. What is the general DIP on other side of the fold axis? ____________________

g. The geologic stress or stress responsible for the deformed feature: ____

h. Tectonic boundary or boundaries that could produce this deformed feature are: ______________________________

____

i. Chose the "paired compass directions" of **stresses** that produce this folded feature. *Draw arrows representing stress to help.*

i. N - S; ii. NE - SW; iii. E - W; iv. SE – NW

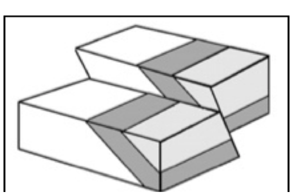
FAULTS: see p. 197-199

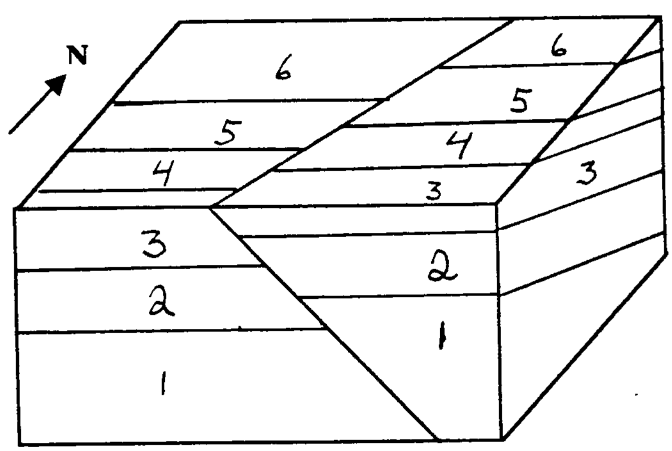
1) The tilted, faulted beds with slickensides showing grooves ***PARALLEL TO DIP OF FAULT PLANE***.

a. Name the type of fault: _________________

b. Add the symbol on MAP view that verifies the rule that dip direction always points toward younger beds.

c. Add fault off-set arrows in proper place.

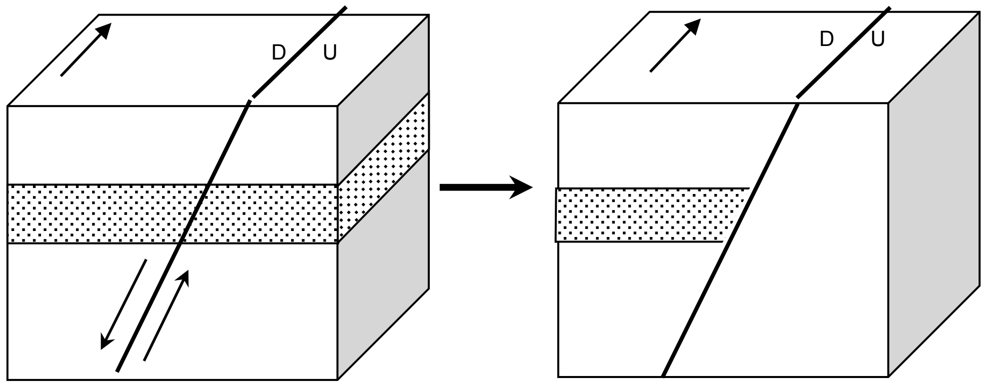




2) COMPLETE THE FAULT DIAGRAMS: ON THE RIGHT BELOW: FINISH BLANK FRONT SIDE OF CUBES

BEFORE FAULTING **AFTER FAULTING**

1.



Type of Fault:

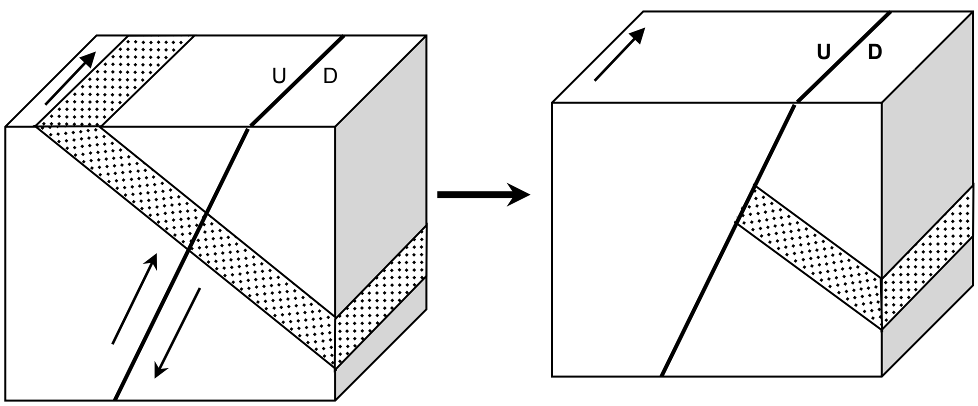
____

Tectonic stress:

____

FINISH blank side of cube
Label Hanging and Footwall

2.



Type of Fault:

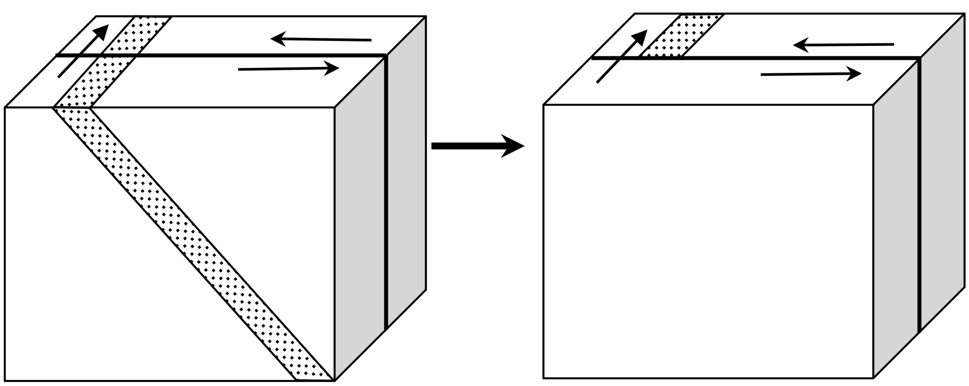
____

Tectonic Stress:

____

FINISH blank side of cube
Label Hanging and Footwall

3.



Type of Fault:

____

Tectonic Stress:

____

FINISH blank side of cube
Label Hanging and Footwall

STRIKE AND DIP BED AND BLOCK EXERCISES

Measure the strike and dip of the two planar objects the instructor has set up in the lab:

a) Planar Object #X - Strike = __________________ **Dip =** ___________

b) Planar Object #Z - Strike = __________________ **Dip =** ___________

TECTONIC STRESS AND FAULTS/PLATE BOUNDARIES

Directions: Complete Columns "B", "C", "D" and "E" below.

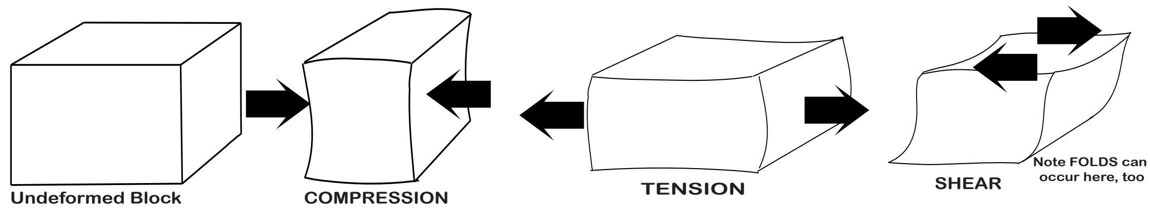
Column A: Block diagrams illustrate three types of crustal faulting.

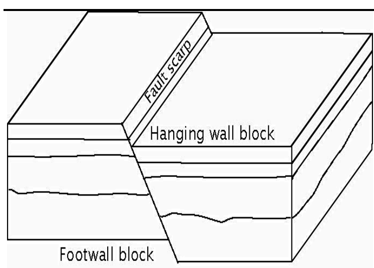
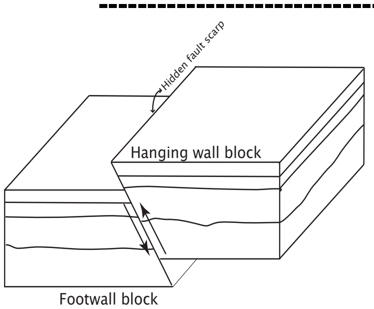
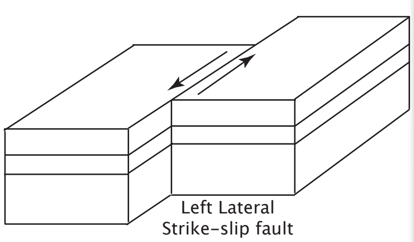
Column B: List changes to Crust surfaces in each case.

Column C: Give names of major fault types (see column "A").

Column D: General type of crustal deformation (stress) associated with type of faulting.

Column E: The type of plate boundary associated with columns "A through "D".



Column A **Block Diagrams**	Col. B **Has crust** Shortened? Lengthened? Neither? **(see type of stress)**	Col. C **Fault Name?**	Col. D **Stress?** Compression Tension Shear	Col E **Plate Boundary?** Convergent Divergent Transform
				
				
				

Structure Laboratory Reflection

Directions: Write a reflection (on the back side of the pages you are turning in today) about your experience in doing the geologic map exercises lab today. Include the following: 1) What was the purpose of the lab?; 2) What did you learned from this laboratory?; 3) What did you find interesting? 4) What were the problems and challenges you encountered; and 5) Your opinion on how this lab was designed. **Write this on the back of the previous page.**

PRACTICE 3-D STRUCTURE MODELS

Directions: In this exercise, you will construct and analyze geologic block models using the six **models provided in the back of your lab manual.** The models are easy to construct by simple folding.

NAME AND DESCRIBE THE STRUCTURE FOR EACH CARDBOARD MODEL
See **Activity 5 p. 213-214 for additional practice questions** for each model.

MODEL 1: ________________________, ____

MODEL 2: ________________________, ____

MODEL 3: ________________________, ____

MODEL 4: ________________________, ____

MODEL 5: ________________________, ____

MODEL 6: ________________________, ____

FOSSILS

Important Information: During the lab final, you will be asked to identify fossils and determine the age (to the Era) of a fossil assemblage. You will be required to identify fossils using the following common names or taxonomic classifications (common names are given in quotation marks).

You should also know the geologic range of the following groups.

- P. Cnideria:
    - C. Anthozoa
    - O. Rugosa (Rugose or horn corals)
    - O. Tabulata (Tabulate corals)
- P. Brachiopoda:
- P. Mollusca:
    - C. Gastropoda
    - C. Bivalvia (Pelecypoda)
    - C. Cephalopoda, “Ammonites”, “Nautiloids”
- P. Arthropoda:
    - C. Trilobita (Trilobites)
- P. Echinodermata:
    - C. Echinoidea
    - C. Crinoidea (Crinoids)

FOSSIL AGE ASSEMBLAGES OF GEOLOGICAL ERAS

Paleozoic – 542 to 251 Ma

Phylim Arthropoda, Class Trilobita “Trilobites”
Phylum Echinodermata, Class Crinoidea, “Crinoids”
Phylum Cnidaria, Class Anthozoa, Order Rugosa “horn corals”
Phylum Cnidaria, Class Anthozoa, Order Tabulata “tabulate corals”
Phylum Brachiopoda, “Brachiopods”

Mesozoic – 251 to 66 Ma

Phylum Mollusca, Class Cephalopoda, “ammonites”
Phylum Mollusca, Class Cephalopoda, “belemnites”
Phylum Mollusca, Class Cephalopoda, “nautiloids”

Cenozoic – 66 Ma to present

Phylum Mollusca, Class Bivalvia
Phylum Echinodermata, Class Echinoidia (sea urchins)
Phylum Mollusca, Class Gastropoda, “fancy”, “armoured” gastropods

EOSC110: FOSSILS LAB

At each station, **observe and sketch the examples** of the fossils you see. Compare them to the pictures in your **handout** and look for the features that are common for each group. During the lab final, you will be asked to identify fossils and determine the age (to the Era) of a fossil assemblage. You will also be required to give the mode of fossilization.

PART 1: MODES OF FOSSILIZATION (pages 143-145)

STATION 1.1: TRACE FOSSILS

A trace fossil provides evidence of animal behavior in the past and may not comprise the remains of ancient organisms.

Examine the examples of the following types of trace fossils and make a guess of what organism produced them:

A: Burrows

B: Worm tubes

C: Boring into a hard rock by a clam.

D: Tracks

STATION 1.2: MODES OF FOSSILIZATION: PRESERVATION WITHOUT ALTERATION.

A: Hard parts. Parts of the original aragonite shell are preserved in these fossils. Eventually, aragnoite, a calcium carbonate mineral that commonly is found in molluscs, will recrystallize to the mineral calcite. But here, these fossils show the original aragonitic shell material.

B. Soft parts. This fossil insect from the Eocene has been preserved in fossilized tree sap, or amber. Amber preservation though very rare provides much of the information we know about delicate insects. The bubbles in the amber preserve a sample of fossilized air from the Eocene. Geochemists have studied ancient atmospheres by analyzing fossil air bubbles in Amber. **Examine this fossil with magnifying lens and list any insects you recognize.**

-
-
-

STATION 1.3: MODES OF FOSSILIZATION: CARBONIZATION

A. The mode of fossilization shown at this station is carbonization. **What is carbonization?**

B. These two samples show well preserved carbonized fossils from the Eocene Green River formation. The Eocene Green River Formation is a fossil-rich deposit in Wyoming and Utah and Colorado which was once an ancient lake.

1. List several fossils that are preserved in the Green River Formation?
   -
   -
   -

C. This sample, which is also from the Green River Formation contains water beetles.

2. Explain why fossil insects are rare?

STATION 1.4: MODES OF FOSSILIZATION: PERMINERALIZATION

Permineralization or petrification is represented at this station.

3. What is permineralization or petrification?

4. What types of fossils shown at this station?

STATION 1.5: MODES OF FOSSILIZATION: RECRYSTALLIZATION, REPLACEMENT, VOID-FILLING CEMENT

At this station are examples recrystallization and replacement.

A. **Recrystallization.** The fossil shells at this station were originally aragonite. However, over time their aragonitic shells recrystallized to calcite. Because the minerals recrystallized on a molecular level, the details of the original shell shape are preserved.

B. This ammonite was originally had an aragonitic shell. The shell was dissolved away by percolating ground waters and pyrite filled in the empty void in the sedimentary rock. This process is called **Replacement.** Replacement by pyrite is often called **Pyritization.**

C. Minerals such as calcite, (as seen here) or chert, often crystallize in the empty pore spaces of fossils to fill the void. This is called **'Void-Filling Cement".** Here we see calcite void-filling cement filling up the chambers of a fossil ammonite. You can see the crystal faces of the void-filling calcite filling the pores. **Draw a diagram** of the sample and draw an arrow indicating the "void-filling calcite".

STATION 1.6: MODES OF FOSSILIZATION: IMPRESSIONS (MOLDS AND CASTS)

A. This is your chance to go back to kindergarten and play with play dough again. Using these shells and the play dough, Make the following (see Fig. 4.1):

  i. Internal mold

  ii. External mold

B. Here are some internal molds.

STATION 1.7: PRACTICE QUIZ: MODES OF FOSSILIZATION.

A. Identify the Modes of fossilization shown here.

A.

B.

C.

D.

E.

F.

PART 2: PALEOZOIC FOSSILS

From http://www.ucmp.berkeley.edu/cambrian/cambrian.php

The Paleozoic is bracketed by two of the most important events in the history of animal life. At its beginning, multicelled animals underwent a dramatic explosion in diversity, and almost all living animal phyla appeared within a few millions of years. At the other end of the Paleozoic, the largest mass extinction in history wiped out approximately 90% of all marine animal species.

Two great animal faunas dominated the seas during the Paleozoic. The "Cambrian fauna" typified the Cambrian oceans; although members of most phyla were present during the Cambrian, the seas were dominated by **trilobites,** inarticulate **brachiopods**, monoplacophoran molluscs, hyolithids, "small shelly fossils" of uncertain systematic position, and archaeocyathids. Although all of these except the archaeocyathids survived past the Cambrian, their diversity declined after the Ordovician. **Later Paleozoic seas were dominated by crinoid and blastoid echinoderms, articulate brachiopods**, graptolites, **and tabulate and rugose corals.**

The Permian extinction, 251.4 million years ago, devastated the marine biota: tabulate and rugose corals, blastoid echinoderms, graptolites, the trilobites, and most crinoids died out. One lineage of crinoids survived, but never again would they dominate the marine environment.

STATION 2.1. PHYLUM CNIDERIA, CLASS ANTHOZOA, "CORALS" (p. 167 Fig. 4.17)

Corals are in the Phylum Cnidaria. Corals are like sea-anemones that secrete a hard skeletal cup in which they sit. The Class Anthozoa includes three orders of corals which commonly occur in the fossil record. The orders are the Order Tabulata (tabulate corals) (Ordovician to Permian) and the Order Rugosa (rugose or horn corals) were common fossils in the Ordovician to Permian period of the Paleozoic.

A. Fossils marked here represent the **tabulate corals**. There corals are exclusively colonial. They have prominent tabula and are missing septa. Compare these to the pictures in the handout **(p. 167 Fig. 4.17)** to see if you can identify the **"chain coral" *Halysites*** (see handout) and the **"honeycomb coral" *Favosites*.**

Draw examples:

"chain coral" *Halysites* **"honeycomb coral" *Favosites***

B. These rugose corals (commonly called "horn corals") are characterized by prominent septae and a horn-like shape. Unlike tabulate corals, these corals can be solitary or colonial. Compare these fossils to the pictures in Fig. 4.17 p. 167.

Draw an example:

rugose corals "horn corals"

STATION 2.2: PHYLUM BRACHIOPODA "BRACHIOPODS" (p. 171-174 Fig. 4.19 and 4.20)

A) Although members of the Phylum Brachiopoda or brachiopods are still around, their taxonomic diversity has decreased greatly since the Paleozoic and most genera are extinct. Examine the diversity diagram in **Figure 4.19 p. 171 (bottom right**) of the handout. During what geologic Period(s) were brachiopods most diverse?

____

B) Observe these specimens at this station and compare them to the pictures in **Figures 4.19 and 4.20**. Draw a diagram of **one specimen** at this station.

1) **Draw the side view** labeling the pedicle valve & brachial valve.

2) **Draw a view from the top ("map view") of one of the valves** with a line of symmetry running through the center of the valve. Are the left and right sides of each valve mirror images? ________________________

a. Try to match one specimen at this station to one of the brachiopods depicted **in Fig. 4.20 p. 172**.

STATION 2.3: PHYLUM ARTHROPODA, CLASS TRILOBITA, TRILOBITES (p. 183 Fig. 4.28)

A) The fossils at this station part of an extinct class of Arthopods (insects, crustaceans, etc.) called the Class Trilobita, or "trilobites". Trilobites got their name because their segmented bodies can be divided into three lobes. Like many other arthropods, these fossils molted their exoskeleton many times in their life. The exoskeleton would break open along the facial suture and the animal would molt the old skeleton and grow a new one (see Figure 4.28g on the handout). This phenomenon made their fossil record even better.

1) Draw a sketch of a specimen and label the cephalon, thorax and pygidium, the eye and glabella (see Fig. 4.28 c, g on p.183).

2) Examine the diversity through time diagram in the upper right-hand corner of Fig. 4.28. During what geologic period did trilobites reach their maximum diversity?

____

3) Here are several trilobite reproductions (fake fossils). Try to match at least two of the reproductions to pictures in Figure 4.28.

STATION 2.4: PHYLUM ECHINODERMATA, CLASS CRINOIDEA, "CRINOIDS" (p. 185 Fig. 4.29)

A) The phylum Echinodermata includes sea stars, sea cucumbers, and sea urchins. Stalked, sessile (attached) echinoderms, such as crinoids (Class Crinoidea) lived attached to the sea-floor by a stalk. Although a few species of modern crinoids (sea lilies) inhabit generally deep-water or sheltered environments, they are uncommon in the modern ocean. However, during some periods of the Paleozoic, a great diversity of stalked crinoids covered the floor of shallow seas. The stalk (or column) consisted of stacked poker chip-like calcite plates (columnals) with a hole in the center. Sometimes the stalks and holes show five fold symmetry and sometimes they are round. Draw a sketch of one of the crinoid replicas at this station and label the crown and stem (column).

Sketch: label the crown and stem (column) p. 185 Fig. 4.29

B) During what **geologic period** of the Paleozoic were crinoids most diverse? _________________________

C) Commonly, their stalks (columns) would break apart into individual columnals (poker chips) which littered the Mississippian and Pennsylvanian sea floor. Crinoid columnals are common constituents of these shallow-water limestones of late Paleozoic age. These crinoid columnal-rich limestones are called "encrinoidal" limestones. Examine these stalks, columnals, and encrinoidal limestones.

PART 3: MESOZOIC FOSSILS

From: http://www.fossilmuseum.net/Paleobiology/Mesozoic_Paleobiology.htm

Mesozoic means "middle animals," and is the time during which the world fauna changed drastically from that which had been seen in the Paleozoic. Dinosaurs, which are perhaps the most popular organisms of the Mesozoic, evolved in the Triassic, but were not very diverse until the Jurassic. Except for birds, dinosaurs became extinct at the end of the Cretaceous.

The Permian-Triassic (P/T) Extinction Event marked the end of the Permian Period of the Paleozoic Era, and the start of the Triassic Period of the Mesozoic Era. **The P/T extinction decimated the brachiopods, corals, echinoderms, mollusks, and other invertebrates. The last surviving trilobite also did not survive**. The P/T event set the stage for adaptative radiation in both land and environments. **While crinoids** were the most abundant group of echinoderms from the early Ordovician to the late Paleozoic, they **nearly went extinct** during the Permian-Triassic extinction.

Other invertebrates, notably the **bivalves, ammonoids, and brachiopods recovered to dominate the marine environment, and the squid-like Belemites appeared and became abundant. New groups of echinoderms appeared as well. Baculites, a straight-shelled ammonite, flourished in the seas**. The Cretaceous also saw the first radiation of marine diatoms in the oceans.

STATION 3.1: PHYLUM MOLLUSCA, CLASS CEPHALOPODA, "Ammonites" & "Nautiloids" (Fig. 4.25, 4.26 p.179-180).
http://www.ucmp.berkeley.edu/taxa/inverts/mollusca/cephalopoda.php

The class Cephalopoda includes the nautilus, octopus, squid and cuttlefish. Shelled cephalopods called "ammonites" and "nautiloids" (related to the modern nautilus) filled many ecological nitches and are common fossils during the Mesozoic. They went extinct at the end of the Mesozoic at the same time as the dinosaurs. Examine **the illustrations of the Mesozoic cephalopods** in **figures 4.25 and 4.26 p. 179-180.**

A) Examine this shell of a **modern *Nautilus*** and compare it the image in the upper left corner of Fig. 4.25. Nautiloids are characterized by a chambered shell with gas-filled chambers used to control their buoyancy.

B) These are uncoiled (orthoconic) nautiloids like those in Fig. 4.25 c, d, and e. They moved vertically in the water column by adjusting their buoyancy by filling chambers in their shell with gas. Individual chambers are separated from one another by walls called septa. Compare the orthoconic nautiloids to the modern shell of the *Nautilus*.

C) Ammonites evolved septa of increasing complexity throughout the Mesozoic. The pattern resulting from the intersection of the septa with the outer shell wall is called the suture pattern. Observe the wide variety of shapes, coiling patterns, and sizes of the ammonites. Compare the specimen to the pictures in Figure 4.26. Although the Ammonites ruled the Mesozoic ocean, they went extinct at the Cretaceous/Tertiary boundary, 65 million years ago.

D) ***Baculite**s* is an uncoiled (straight) ammonite (Fig. 4.25 f). Examine these samples and **sketch the suture patterns.** Are they complex or simple? Compare the uncoiled ammonite *Baculites* to the orthoconic nautiloids.

Sketch of suture pattern:

E) These cigar-shaped fossils (belemnoids) were the internal skeletons of squid like organisms that roamed the Cretaceous seas.

STATION 3.2: CLASS VERTEBRATA, CLASS REPTILIA, "Dinosaurs".

While the ammonites ruled the seas during the Mesozoic, these organisms ruled the land.

PART 4: CENOZOIC FOSSILS

The following is from: Earth through Time, 8th ed. by Harold L. Levin

The invertebrate faunas of the Cenozoic have a modern appearance.

Once-successful groups of invertebrates such as the ammonites and rudist bivalves went extinct at the end of the Cretaceous. The shells of Cenozoic molluscs look like those found on beaches today. The Cenozoic molluscs are dominated by bivalves (clams) and gastropods (snails). Cephalopods are also present, however, not as widespread and abundant as during previous periods when the ammonoids were still present. Modern cephalopods include the chambered *Nautilus*, as well as other forms without a shell (or with a reduced shell) such as squid, octopus, and cuttlefish. Echinoderms are also present in the Cenozoic, particularly free-moving types (as opposed to the attached crinoids of the Paleozoic). Echinoderms include the echinoids (sea urchins, sand dollars, sea biscuits), and the starfish. Modern crustaceans (such as crabs, shrimp, lobsters, barnacles) became well established in the seas during the Cenozoic**. No new major invertebrate groups appeared in the Cenozoic.**

Dominant invertebrates of the Cenozoic include:

- Sponges
- Scleractinian corals - modern reef corals (Phylum Cnidaria)
- Bryozoans
- Brachiopods (both articulates and inarticulates)
- **Molluscs**
    - **a. Bivalves**
    - **b. Gastropods**
    - c. Cephalopods
- Arthropods
    - a. Crustaceans
    - b. Insects (on land)
- **Echinoderms**
    - **a. Starfish**
    - **b. Echinoids (sea urchins sand dollars, and sea biscuits)**

STATION 4.1 PHYLUM MOLLUSCA, CLASS GASTROPODA "SNAILS" (p. 177-178, Fig. 4.23)

A) The Class Gastropoda or "gastropods" include snails and slugs. Though gastropods have been found throughout all the eras of the Phanerozoic, in the Cenozoic they evolved a more ornamented shell with high spires, and a siphonal canal. Examine the images in Fig. 4.23 for examples of gastropods typical of the Cenozoic Era. By contrast, the more simple ancient gastropods (archaeogastropods) that were found in the Paleozoic are shown in Fig. 4.24.

STATION 4.2: PHYLUM MOLLUSCA, CLASS BIVALVIA, "CLAMS" (p. 174-175, Fig. 4.21, 4.22)

A) Examine the diversity diagram in 4.21. When did the bivalves (Class Bivalvia) reach their maximum diversity?

B) **Sketch the inside of one of these shells and label the muscle scars (adductors), pallial line, and teeth and sockets**. The pallial sinus is an indentation in the pallial line. Deep burrowing types have a larger pallial sinus than shallow-burrowing or non-burrowing types. Did this specimen burrow in the sediments or live on the surface of the ocean floor?

Sketch:

C) How do bivalves (clams) differ from brachiopods (Station 2.2) in appearance?
Look at symmetry of shell

Sketch: Brachiopod symmetry   Bivalve symmetry

D) Compare these specimens you see at this station to the images in Figure 4.22 p. 175.

STATION 4.3: PHYLUM ECHINODERMATA, CLASS ECHINOIDIA (Fig. 4.30)

These sea urchins, sand dollars, and heart urchins (Class Echinoidea) inhabit epifaunal (on the substrate), semi-infaunal (partially buried in the substrate), and infaunal (buried) habitats, respectively. Whereas the sea-urchins maintain their five-fold symmetry, the sand dollars and heart urchins have evolved secondary bilateral symmetry. This secondary bilateral symmetry appears to be adapted to a life of burrowing, where it is advantageous for the organism to have a more elongated rather than round shape. Echinoids reached their maximum taxonomic diversity in the Cenozoic.

Sketch 2 samples:

STATION 5: FOSSIL ASSEMBLAGES

Each of the stations includes a group of fossils that could have been found during one of the eras of geologic time. For each fossil assemblage, identify each fossil as specifically as possible and determine the geologic ERA represented by the assemblage.

PART A QUIZ:

ERA: ____________________________

A)

B)

C)

D)

E)

F)

PART B QUIZ: Place each fossil with the correct Era (you decide where to place A through F).

ERA: ____________________________   **ERA:__________________________**

-
-
-

Please return fossil manual. This will be available on Bb for review.

GEOLOGIC MAPS **Name: ___________________________**

Introduction:
A geologic map is a scaled-down, two-dimensional abstract representation of the surface geology, structure, and relief of a geographic region of Earth or other terrestrial planet. A geologic map typically includes most of the information found on a topographic map but most importantly also includes color-coded regions and symbols that denote rock units, ages, contacts, and other structural information. All of the geologic color-coding and symbols are explained in the legend on a geologic map, including topographic and cardinal-point compass information.

A. READING AND INTERPRETING A GEOLOGY MAP
Directions: First do a general examination of the entire geologic map of the **DEVIL'S FENCE QUADRANGLE.** Carefully examine the various rock units represented by the colored regions and related map symbols on the map that portray the surface geology of this area in the Rocky Mountains. Note their shape, aerial extent, and the larger structural patterns formed by spatially- associated outcropping rock units. Use the "Explanation" part of the map to decipher the rock units, in terms of formation name, **age**, and lithology. Also use the explanation to the left of the map to decipher the structural relations of the various formations, including strike and dip, folding, faulting and **age ranges** of formations. Finally, answer the following questions, based on your analysis of the Devil's Fence Quadrangle.

DEVIL'S FENCE QUADRANGLE.

GEOGRAPHIC AND TOPOGRAPHIC QUESTIONS (include all appropriate unit abbreviations)

1) What state is this region located in? ____________________

2) What is the magnetic declination for this region? ____________________

3) What is the map and verbal scale for this map? ____

4) What is the contour interval of this map? ___________________

5) How many square miles does this map cover? _______________________

6) What is the total vertical relief for this area? __________________

7) What ***topographic*** feature (hill, ridge, valley, etc.) does Devil's Fence correspond with? ____________________

8) What ***geological*** feature (syncline, anticline, fault, etc.) is the Devil's Fence area? ________________________

GEOLOGIC QUESTIONS

9a) List the major lithologies in this area, as listed in the map legend. Include at least six rock types.

____________, __________, ______________, ___________, ____________, and _____________.

9b) What is the total range in age for the various rock types found on the map? ___________ MY's

10) How old is the Colorado Formation? __________ ma Locate this unit on the map.

11) This rock unit forms the center of what general type of deformational geologic structure, such as a fold or fault? (hint: notice the upside down "V" shaped pattern of rocks) _________________.

12) If you wrote down "fold", is it a syncline or an anticline? ______________________

13) What information did you use to tell whether it was a syncline or an anticline? _______________

____

14) Is it a horizontal or plunging fold? __________ . How could you tell? _____________________

15) Determine the strike of fold axis _____ If plunging, then which direction is the fold plunging? ____

16) How old is the Grayson Shale? __________ ma   Locate this unit on the map.

17) This rock unit forms the center of what general type of deformational geologic structure, such as a fold or fault? (hint: notice the upside down "V" shaped pattern of rocks) _________________.

18) If you wrote down "fold", is it a syncline or an anticline? ______________________

19) What information did you use to tell whether it was a syncline or an anticline? _______________

____

20) Is it a horizontal or plunging fold? __________ . How could you tell? _____________________

21) Determine the strike of fold axis _______ If plunging, which direction is the fold plunging? ______

22) How many distinct folds are shown on this geologic map? *Hint: Way more than two!* ______

23) The deviatoric stresses that caused the folding come from which two compass directions? _____

24) When did the folding event occur? *Hint: It happened **after** the age of the youngest folded rock formation, but **before** the oldest non-folded rock formation.*

Deviatoric stress: ¦dēv·ē·ə¦tör·ik 'stres) (geology) A condition in which the stress components operating at a point in a body are not the same in every direction. Also known as differential stress.

GEOLOGIC MAP EXERCISE 2: LA JOLLA QUADRANGLE

1. What is the name and age of Ta?____

2. What is the name and age of Kcs?_______________________________________

3. What is the name and age of Qln?_______________________________________

4. What is the regional (average) elevation of mesas that are capped by Qln? ____________________

5. What is the elevation of Mt. Soledad where Ta and Kcs outcrop (more than one location)? ___________

6. Mission Valley and San Clemente Canyons are generally east-west trending valleys that dissect the mesas. Are there two valleys stream erosion valleys or are they fault-controlled?

7. Interstate 5 runs north-south along Rose Canyon, east of Mission Bay, separating Mt Soledad from the mesas to the east. Parts of Tecolote Canyon (north of USD) trend parallel to Rose Canyon. Are the I-5 valley and Tecolote Canyon normal stream erosion or fault-controlled valleys?

8. Use the C-C' cross section to determine the type of fold that is observed in Pacific Beach. _______________

9. Observe the unnamed fault east of the Rose Canyon Fault Zone. Indicate (circle one) the fault type:
normal reverse strike-slip.

10. Use the B-B' cross section to determine the type of fold associated with Mt. Soledad. ________________

11. Follow the trace of the Rose Canyon Fault Zone from Mission Valley along I-5 to La Jolla Cove, where it goes offshore. What are the three primary faults that comprise the Rose Canyon Fault Zone?

-
-
-

12. Compare cross sections B-B' to C-C'. State whether the Pacific Beach Syncline is plunging or horizontal. If plunging, give the compass direction (N or S) and **evidence to support** your answer.

13. What is the age, rock type and formation name of rocks on which USD is built? Give the same information about the rocks that outcrop on the sloping hills around USD.

- USD:
- Sloping Hills:

14. An inactive branch of the Old Town Fault (part of the Rose Canyon Fault Zone) cuts through Marion Way and under Camino Hall.
a. What is the approximate strike and dip of this fault? ____

b. In what rock formation is it visible on the surface? ____

15. Examine cross section C-C' that crosses USD.

a. If you wanted to drill from behind Serra Hall, how deep would your hole need to be in order to reach Cretaceous-aged rocks?

____

b. Locate where the trace of the Pacific Beach Syncline intersects cross section C-C'. If you drilled a similar hole at the hinge line (axis) of the PB Syncline, approximately how deep would you drill before you encountered Cretaceous-aged rocks?

c. Why is the depth of the Cretaceous rock so different in these two locations? Explain with a diagram:

HOPE YOU ENJOYED THE COURSE!